13

S. HRG. 103–362

USES OF ADVANCED MATERIALS IN CIVIL INFRASTRUCTURE

Y 4.C 73/7:S.HRG.103-362

Uses of Advanced Materials in Civil...

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED THIRD CONGRESS

FIRST SESSION

MAY 27, 1993

Printed for the use of the Committee on Commerce, Science, and Transportation

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USES OF ADVANCED MATERIALS IN CIVIL INFRASTRUCTURE

THURSDAY, MAY 27, 1993

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY,
AND SPACE OF THE COMMITTEE ON
COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The committee met, pursuant to notice, at 10:15 a.m., in room SD–628, Dirksen Senate Office Building, Hon. John D. Rockefeller IV (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Patrick H. Windham, professional staff member; and Louis C. Whitsett, minority staff counsel.

OPENING STATEMENT OF SENATOR ROCKEFELLER

Senator ROCKEFELLER. Welcome to all of you. Thank you for coming. Some of you are from across the country, and others from places closer.

This hearing is the first in a series that Senator Burns and I want to have on a critical question and that is: How can advanced technologies help meet major needs of our nation, ranging from civil infrastructure to, in fact, health care and, generally, to economic competitiveness?

We believe, both of us, very strongly that Federal research programs have responsibility to help private industry where that is appropriate. And the states can improve their prosperity and their public welfare through this.

Civil infrastructure is a fitting subject to start with at a time when Federal and State budgets are tight, but our population is growing. Governments everywhere are under pressure to find better and to find less expensive ways to provide essential infrastructure projects such as highways, bridges, and water systems.

The value of the Nation's public works infrastructure is reported to be $2.7 trillion. That is everything in the way of roads, bridges, highways, water systems, sewer systems, and the rest of it.

And the annual repair and maintenance costs are, of course, enormous where they are being done, and not deferred. Private investments in homes, buildings, and other private infrastructure totals tens and tens of billions of dollars, of course, more than that.

Clearly, if new technologies can help improve the durability of our infrastructure and reduce cost, the savings can be enormous. And we will need to find the ways to achieve those savings.

In addition to saving money, new infrastructure technologies can also make the U.S. construction industry more competitive than it currently is in world markets. The construction industry totals over 8 percent of America's gross domestic product.

And U.S. construction firms have long been very competitive on a worldwide basis. But as in so many other industries, companies in Japan and Germany and elsewhere are adopting the most advanced technologies, often with the help from their governments.

Our companies face, therefore, a very real competitive challenge and even a threat, unless we take some kind of appropriate and useful action. Fortunately, this country's companies and universities are neck deep in new technologies, including valuable new materials, such as high-performance concrete, improved steel, advanced composites, and advanced ways of using woods.

These new materials offer incredible promise: highways that last much longer—the thought of a highway without a pothole for 50 years is of interest, at least in West Virginia—lightweight bridges that do not rust, and second skins, so to speak, of composite materials that can be applied to existing structures to improve their resistance to both earthquakes and corrosion.

The problem we face is how to get these promising materials out of the laboratory and into the marketplace, the classic American dilemma. That is not always as easy to accomplish as we would like to see it.

When first introduced, new materials can be expensive and can be difficult to manufacture. And customers have to be shown that they, in fact, can do the jobs, these new technologies.

As in other areas of technology, companies are looking for ways to overcome technical problems, improve manufacturing, obtain financing, gain experience, and demonstrate performance.

And increasingly, we can see imaginative proposals for Government-industry-university partnerships, all three, to help share costs and speed the commercialization and the adoption of these new technologies.

That is the point of the discussion of this particular hearing. So, we will focus on three specific issues this morning: First, what are the Nation's civil infrastructure needs? And what are the best ways in which advanced materials can help those needs?

Second, what hurdles, technical, financial, and market-related, do both small and large American companies face in commercializing and demonstrating these new materials? And how do these hurdles affect the competitiveness of the U.S. overseas?

And then third, what role can Federal research and technology programs, in fact, play in helping firms overcome these same obstacles? Mr. Chairman, your comments, please.

OPENING STATEMENT OF SENATOR HOLLINGS

The CHAIRMAN. I am pleased that the Science Subcommittee is holding this morning's hearing on the uses of advanced materials in civil infrastructure. For the past 6 years, this committee has placed a great emphasis on making Federal technology programs more useful to society as a whole. In a time of tight budgets and a changing world, we need to make sure that Federal research programs are doing as much as possible to meet national needs. For

example, S. 4, a bill which I introduced earlier this year and which the Commerce Committee ordered reported on May 25, 1993, strengthens Federal technology programs to ensure that new technologies are better commercialized and that the Nation's global competitiveness is promoted. In the area of advanced materials for use in building the Nation's infrastructure, this hearing will provide us with the opportunity to review public- and private-sector research and development programs, the interaction among them, and the commercialization of new technologies. An efficient and cost-effective national infrastructure is an important national need.

I look forward to reviewing the testimony of today's distinguished witnesses, and to further work on these important issues.

Thank you, Mr. Chairman.

Senator ROCKEFELLER. Thank you, Mr. Chairman. We are fortunate to have a very distinguished and very patient group of witnesses. They are experts in both advanced materials and civil infrastructure. And I am pleased to say, they include one of our top civil engineering professors at West Virginia University.

I thank all of you. You happen to be four men. In fact, I see only three women in the audience. And I am curious about all of that, but times will change on that. Times will change.

Dr. Borleske, why do we not start, sir, with you, because I think you are going to kind of give us an overview?

Dr. BORLESKE. Yes. Thank you.

Senator ROCKEFELLER. But first we will hear from Senator Burns.

OPENING STATEMENT OF SENATOR BURNS

Senator BURNS. Well, thank you, Mr. Chairman. I appreciate your interest in this.

You gentlemen, I thank you for coming. Senator Rockefeller and I had a meeting—it was a very fruitful meeting—before, when we got our committee assignments. And I am just tickled to death to be on this particular committee with Senator Rockefeller, because everywhere we have served with each other, it has been sort of a cooperative thing. And this was high on his calendar. It is also high on mine.

New materials, new technologies, new techniques are coming out everyday. And one of the big problems that we have is, as Senator Rockefeller knows, I come out of county government.

And it is getting this technology into the place where it will do us the most good. We know that we are going to have to make continuing investments in our infrastructure, our transportation, roads, bridges, and everything else that makes our communities click.

The thing about it is—where we run into problems is the classic example of what Senator Rockefeller says. How do we do things different? And that is, we have to reeducate those people who are not sitting on this committee, but who are sitting in the chambers of county commissioners, State legislators, who understand that we have this technology.

We have these new techniques to do things better. And we are still operating with the old horse and buggy when we are supposed to be on high-speed rail now.

And so that is where we run into problems. We continue to do things the old way, because we have the forces out there that say, "Hey. We do not want to change. He is a friend of mine. He still builds a steel bridge. And he helped me get elected, so we got to help him along. And he does not want to make the advancement in new technologies."

We have to face up to the fact that we are going to have to do some things differently and a little bit better in order to get it done. And I, for one, like Senator Rockefeller, understand that.

Let us face it: We invented and pioneered the VCR, but we are not making them in this country. We are talking about telecommunications, broadband telecommunications, and how that infrastructure will absolutely revolutionize real America and the way we do business, how we transmit, how we move information.

And the implications for education and health care delivery in broadband telecommunications will be just absolutely mind-boggling, but we have yet to catch the imagination of the American people to build a fire that this is going to be part of an infrastructure that will be very necessary.

I think Senator Rockefeller understands that. So, we have a very good working relationship. And we understand that some things are going to have to change before we make monumental leaps for all of society, not just a particular part of it, but I mean all Americans. This has to be for everybody whenever we start going down this road.

So, Senator Rockefeller, I appreciate your efforts on this and your leadership on this. And I just want to be a part of it and contribute to whatever I can.

So, I thank you for coming. Now, I am going to jump up and run out of here in a little bit, because I am also on appropriations. I am one of these big spenders you have heard about here in Washington.

So, we have to go down and spend some money this morning on something that is very close to his heart again. And that is, on his committee—we are talking about Veterans Administration. So, I am sort of wearing two hats here today, but the spots never change.

Thank you very much.

[The prepared statement of Senator Burns follows:]

PREPARED STATEMENT OF SENATOR BURNS

Mr. Chairman, I want to thank you for holding this hearing on the use of advanced materials in our Nation's infrastructure. Our civil infrastructure is in poor shape as result of years of neglect, abuse, and overdemand. For example, the National Highway Administration has reported that about 45 percent of the Nation's bridges are in immediate need of repair. Clearly addressing this problem should be a national priority.

As far as the Science Subcommittee is concerned, it is our obligation to ensure the U.S. know-how in advanced materials is brought to bear on this national crisis. Composites and other high-technology materials are stronger, more durable, more corrosion-resistant, and less susceptible to defects than the steel and concrete that we have come to rely on. Moreover, the advanced materials could dramatically reduce the amount of concrete used for bridges and roads. In fact, it has been estimated that the use of advanced materials could produce costsavings for the construction industry of about $100 million a year.

Beyond improving our infrastructure, U.S. advanced materials R&D are critical to the competitiveness of our construction industry. Although construction is one of

the largest U.S. industries, intense foreign competition and a lack of private sector R&D are eroding the technological leadership of the United States. Japan in particular is gaining ground and this is largely due to its commitment to construction-related R&D.

U.S. labs are developing some fascinating technologies. I understand that scientists are working on self-monitoring materials that will provide continuous feedback on the health of the bridges and other structures. Work is also being done on self-healing materials. These materials would contain fibers filled with sealant that would be released whenever the material is cracked. In addition, there is work on "second skins" that could be applied to strengthen ailing bridges and protect them from corrosion. The list of technologies is endless.

However, the challenge is getting these technologies out of the lab and into the marketplace. We have on-the-shelf high-technology materials from the aerospace and military industries right now that have yet to be applied to our construction needs. Too many times, our competitors have managed to commercialize our inventions before we could. We invented the VCR, yet, today no American company manufactures VCR's. We must not let the same thing happen with respect to advanced materials research. I will look forward to hearing the thoughts of our witnesses about how the United States can do a better job of putting materials like composites and self-healing substances to work in our bridges, roads, and buildings.

One final point that I would like to make is that too often this subcommittee hears that the answer to a technology problem is to create a new billion dollar program. In fiscal year 1993, the Federal Government expects to spend $2 billion on the multiagency advanced materials research. It is unlikely that throwing more money into Federal R&D will resolve the problem of applying and commercializing our advanced materials research. I would like to hear more about how we can work within existing programs and budgets to develop a strategy for encouraging industry to make the appropriate investment.

Mr. Chairman, thank you again and I look forward to hearing from our panel of distinguished witnesses.

Senator ROCKEFELLER. Can I make one point about the Veterans Administration? One of the things that the Clinton administration has done is cut out, very wrongly, in my judgment, the money that is——

Senator BURNS. Research.

Senator ROCKEFELLER [continuing]. Research. And the reason—gentlemen, excuse me for the moment. But the reason of the importance of research is the fact of the possibility of research which allows, and only that, which allows the VA hospitals to keep their top medical people.

Senator BURNS. Yes.

Senator ROCKEFELLER. If the research goes, their top people go, because they can get the research elsewhere.

Senator BURNS. You read my speech.

Senator ROCKEFELLER. Did I? That is wonderful. That is wonderful.

Senator BURNS. See, we are together.

Senator ROCKEFELLER. Democrats and Republicans together.

Senator Gregg.

Senator GREGG. Well, I am just here to listen.

Senator ROCKEFELLER. OK.

Senator GREGG. So, let us get going.

Senator ROCKEFELLER. All right. Dr. Borleske from DuPont. Please proceed, sir.

STATEMENT OF DR. STEPHEN G. BORLESKE, DEVELOPMENT MANAGER, ADVANCED MATERIAL SYSTEMS, DUPONT CO.

Dr. BORLESKE. Senator Rockefeller, distinguished members of the subcommittee, my name is Steve Borleske. I work for DuPont as

a new business development manager in the advanced material systems business.

I am also active in a variety of trade association, material trade associations and societies, working to build consensus among the industry.

Last year, I had the honor to serve the industry as a congressional fellow on the House Committee of Science, Space and Technology. During that process, I learned how difficult your job is.

I am honored to be here today to testify on using advanced materials in civil infrastructure modernization. For my testimony today, I would really like to establish three points with the subcommittee.

No. 1, the best way to create new, high-quality jobs, spur growth in the national economy, and solve some of our pressing societal needs is to speed the commercialization of U.S. advanced technologies. The Government must serve as a stimulus for adoption of advanced technologies, not just invention.

Point No. 2, the Nation's infrastructure, which is so vital to our standard of living and global competitiveness, is aging and needs improving.

Advanced materials and systems technology have the potential to contribute significantly to solving our Nation's infrastructure problems, but these technologies will not be commercialized in the current traditional and fragmented construction business environment.

Point No. 3, the Federal Government, through the Department of Transportation, Department of Energy, General Services Administration, and other user agencies, is the influential first customer for the infrastructure improvements.

In cooperation with industry, Government must use modern business practices to accelerate the development and commercialization of the advanced technologies, such as advanced materials and systems.

Sponsoring joint industry, Government, academic demonstration and insertion programs focused on a strong market need is one of the key vehicles to do this. In addition to the role as the customer, the Government is also the enabler through organizations such as ARPA, NIST, and NSF.

Let me develop these points by describing advanced materials, the advanced materials industry, the infrastructure problem—and I think you did a very fine job of describing the dollars and the magnitude this morning—and the construction industry.

Let me also talk about infrastructure partnerships in action today, emphasizing what DuPont is doing, and finally, some specific recommendations for the subcommittee.

Advanced materials are polymers, ceramics, metals, and mixtures thereof that because of their unique chemistry and structure have properties such as much higher strength, stiffness, higher temperature resistance, and chemical stability.

They are commonly used in metals, woods, and plastics that we use today. We generally think of them as space age materials that allow us to land a man on the moon or to build high-performance military equipment.

Today we are beginning to recognize that many of the same properties may also have high value when used in down-to-earth applications, our bridges, our cars, or our sewer pipes.

The advanced materials civil technology has been designated as one of our national critical technologies important to both military and civilian competitiveness.

Potentially, by the turn of the century, the market for the advanced materials represent a $400 billion global market opportunity and 1.5 million good, quality jobs for American citizens.

Senator ROCKEFELLER. Would you repeat the last? How many?

Dr. BORLESKE. 1.5 million high-skilled jobs for American workers.

Senator ROCKEFELLER. Million?

Dr. BORLESKE. Yes, million.

Senator ROCKEFELLER. 1.5 million.

Dr. BORLESKE. Yes.

Senator ROCKEFELLER. OK.

Dr. BORLESKE. But this will only happen if there is market pull to draw these technologies into continuous use. The industry was developed in the seventies and the eighties on the promise of very profitable markets in the defense and in the aircraft/aerospace arena.

For the most part, the initial customer for these products was the Government. And today, both of these markets are very strongly depressed. And many of the quality jobs in this industry today are at risk.

Over the past year, industry has been working aggressively together with trade associations and societies to develop an industry perspective on: What is the problem, and what are the solutions?

These are summarized in two reports, which I will ask to have entered into the record: The "Advanced Materials Agenda for the Clinton Administration and the 103d Congress," by the Suppliers of Advanced Composite Materials Association and the U.S. Advanced Ceramics Association, and also the "Materials Industries' Strategic Needs for the 21st Century," by the Federation of Materials Societies. In reading these reports, you will find that industry is ready to do its part.

Let us turn and talk about infrastructure problems. The problems of America's decaying infrastructure is well known. The report to the Office of Technology Assessment describes the needs well.

You described some of the magnitude of those dollars this morning. Each year taxpayers will pay billions of dollars due to the lack of materials durability, construction methods that disrupt public use of the facilities for a long period of time, and the ever increasing maintenance requirements.

The reward for bringing new technology to the infrastructure business is of national scale. The Transportation Research Board, for example, has calculated that improving the durability of America's roads and bridges by just 1 percent will save between $10 and $30 billion over a 20-year period.

With that kind of a financial carrot, the logical question for you to ask is: Why are not America's industries aggressively pursuing

these new markets? The answer is very straightforward: No one company can afford the risk to bring innovation to the industry.

In sharp contrast to other industries, the construction industry is very fragmented, with over 1 million firms. These individual firms cannot afford the research and development. In addition, there are many barriers in the form of codes, regulations, and specifications, not only at the Federal, but the State and local level.

Very simply put, the public need is well-documented. And the promising technological capabilities exist. American industries, like DuPont, cannot afford to bring innovative technologies to this market. How do we solve this——

Senator ROCKEFELLER. Can I just——

Dr. BORLESKE. Yes.

Senator ROCKEFELLER. Senator Gregg, you do the same thing when you have a question.

When you say that a company like DuPont has, say, a flexible concrete, like has been done at West Virginia University, what happens?

Dr. BORLESKE. If I had it, it would be very difficult to commercialize that.

Senator ROCKEFELLER. Well, then why could you not take that to one of these big construction companies that do interstate highways? Why could not you take——

Dr. BORLESKE. Simply because the—yes, we could. It would take 10 years to get to market. And I could not afford to pay my research and development people during that 10-year period.

Senator ROCKEFELLER. OK.

Dr. BORLESKE. Because it is—it is a handoff mechanism. DuPont does all of its developments, and then the construction company goes through its rigorous and lengthy evaluation time period.

And then the various agencies have to look at the codes and how all of this fits in. And then you have to go on that cycle around and around again. That is not a modern business practice.

The solution is modern business practices. We really do not want handouts from Uncle Sam and what have you. We want to do business better. And that is getting in the room at one table, as you have done today, the industry representatives, material suppliers, the users, the design and construction engineers.

The Government really serves two roles, and that is the enabler—and we have NSF here today—and finally, as the customer.

And when you get all of those people in the room at one time talking from day one on, "What is the problem?" and they all contribute to the problem at one time, the result is a dramatically reduced cycle time.

That is what DuPont would like to be involved in the construction infrastructure area, because I personally have worked in the concrete reinforcement area 7 or 8 years ago. We failed.

I put several millions of dollars in research from a number of people. Nothing ever came of that. It is sitting on the shelves today, because we could not put that value chain together.

Senator ROCKEFELLER. That is incredibly important. Please proceed, sir.

Dr. BORLESKE. I have just said in my own words what my testimony says. And I very strongly believe that the good business practices is what the Government needs to pay attention to.

Put that sort of organization together, and you will see very dramatic things happening in the way of bringing innovative technology, not just in the advanced materials industry, but a range of technologies into the marketplace much more effectively.

Senator GREGG. Are you talking about some sort of structured form, a structured form where the Federal Highway Administration——

Dr. BORLESKE. I am talking——

Senator GREGG [continuing]. And the contracting groups and the R&D groups——

Dr. BORLESKE. Yes.

Senator GREGG [continuing]. Sit down and go over new technologies in a structured way——

Dr. BORLESKE. Yes.

Senator GREGG [continuing]. That evaluates them?

Dr. BORLESKE. Very definitely. And the way we are starting to do that today—and let me start going into my own DuPont experience—is that we are forming industry, Government, academic partnerships.

And the reason that you need all three of those there is that the industries like DuPont have some of the materials technologies. The construction firms have design and engineering.

The Federal Highway, both the—the research people are important, but more importantly, it is the people that are on the line that know the problems and what has to happen differently.

One of the things that we have been doing recently is talking to a variety of Department of Transportation people in New York, in Pennsylvania, and other Northeast States of: What are your problems?

And again and again the corrosion problems and others come up. And so we have learned what the problems are. And when you hear that in—if you hear it from the user, then you can all start at the same time in solving the problem.

Now, one thing that, I think, is very important is in contrast to other industries, the universities have a very valuable role in the infrastructure problem and that NSF has done an excellent job of developing the baseline technology, both for materials and for civil engineering.

This industry has not invested in R&D. And the technology currently develops in the university. To be successful—for DuPont to be successful in the business, I need to have very close ties with my university's civil engineering folks at the University of Delaware, West Virginia, the University of California, throughout the country.

Senator ROCKEFELLER. Penn State has good stuff; does it not?

Dr. BORLESKE. Yes. Yes. And you can tick them off. There are probably 20 of them that are excellent through the country.

Senator ROCKEFELLER. Senator Gregg, does it make sense to you not to use a good technology? Let us just take the flexible concrete. I mean, I saw that at West Virginia University 5, 6, 7 years ago.

I held it in my hands. it was about this square, like that. And it was not pure concrete, of course. It was a composite.

Dr. BORLESKE. Yes.

Senator ROCKEFELLER. But it was flexible.

Dr. BORLESKE. Yes.

Senator ROCKEFELLER. Just barely, you could just barely bend it.

Dr. BORLESKE. Is that in use today?

Senator ROCKEFELLER. And I remember thinking, because I was just finished being Governor—and a Governor's life, as Senator Gregg knows, is just full of people complaining about potholes.

And I was thinking: Why do we not use this? We are building interstates. We have Federal highway noninterstate roads. We have secondary roads that belong to the State system.

What is the procedure and the process, the business practices that you referred to, to prevent us from using this? And my question, I guess, would be to any of you: What has happened to that flexible concrete? Where is it today? Is it on a shelf at these various universities, not being used?

Dr. BORLESKE. My industry perception—and I may not have the facts here—is that it is probably on the shelf somewhere, rather than in five different small pads on major roads throughout the country, because what you really want——

Senator ROCKEFELLER. Providing 50 to 75 years of roads——

Dr. BORLESKE. Yes.

Senator ROCKEFELLER [continuing]. That do not get potholes.

Dr. BORLESKE. Because new technology needs demonstration and insertion opportunities to prove them out at the early stage.

Senator ROCKEFELLER. And the Federal Highway Administration, as Senator Gregg said, cannot promote that.

Dr. BORLESKE. The Federal Highway Administration has a very low level of funds for its research and development budget. In many cases, they are trying to do some very admirable things.

But I think we are really entering into a new era over the last year or so where we are really thinking and talking in terms of collaboration, rather than competition. My own division in DuPont has become much more active working with the Government as a partner over the last couple of years, than we did 5, 10 years ago.

So, the world is changing for us. And if you look at the Department of Transportation, I think the main thing that holds them back is budget. And that is why, I think, if you look at Government, Government needs to fund the user agencies for demonstration insertion projects. It needs to use what I call the enabling organizations like NSF, like——

Senator ROCKEFELLER. Well, of course, it does not have a budget problem.

Dr. BORLESKE [continuing]. Like ARPA.

Senator ROCKEFELLER. It does not have a budget problem. It has the Federal Highway Trust Fund, but they are not using the Federal Highway Trust Fund——

Dr. BORLESKE. They do not use the——

Senator ROCKEFELLER [continuing] Because that has been used for deficit reduction.

Dr. BORLESKE. You and I both know that it is there and piled up.

Senator ROCKEFELLER. So, you are not telling me that they do not have the money. You are telling me they are choosing not to spend the money.

They are spending billions on concrete to finish up Appalachian corridors and the Interstate Highway System and Federal roads, et cetera, and are declining to use—to spend money which is clearly available to them, perhaps told by OMB that they cannot spend it. Are they making a fight to try and spend the money?

Dr. BORLESKE. I think they are struggling with the change of roles of what the Federal agencies say they ought to be doing and how they ought to be interacting with industry in what is called industry policy.

I am a very strong believe that industrial policy is really bringing new technology for societal needs to the marketplace, whether it be defense in the military role, or it be transportation issues, or it be health care, or what have you. It is how we redefine industrial policy.

Senator ROCKEFELLER. All right.

Senator GREGG. I would be interested in hearing from Dr. Bordogna on why he thinks the technologies are not getting out there.

I mean, my sense, looking at it from parochial New Hampshire's sense, is that our Department of Transportation simply was not about to take on any technologies that were not approved. And you did not get them approved, because there was no time or effort. Nobody wanted to take on experimentation.

Dr. BORDOGNA. Well, you are asking me that question. I think the major difficulty is twofold. One is that a single agency is not going to be able to handle this. There has to be a partnership among the agencies.

We have talked this morning already about partnership among Government, academe, and industry, which is critical. But the Federal Government itself has to partner. And so you begin to see some connections developing in the last few years with MOU's between agencies for this purpose.

NSF and the Federal Highway Administration, for example, have signed an MOU to try to get at this kind of dilemma. So, I think it is critical to understand that one single agency that may have the name "Highway," that sounds like it is responsible alone for highways, has to connect in some way with other Federal agencies to help meet marketplace needs. That is a critical issue.

The second issue has been mentioned here once and alluded to several times—changing the system out there is difficult.

It is not just "Somebody has built a bridge and was a friend for many years," but the codes themselves are intricate. And there are thousands of them. And we have to work on changing them. So, NIST comes into play here, because it understands how to create codes. NIST, the Federal Highway Administration, and NSF and others must connect to do this.

There is an opportunity now for a practical try at this through defense conversion. There now is a technology reinvestment project underway for $500 million, which aims at applications like this. Infrastructure dilemmas are certainly part of a dual-use kind of thing. Many of the advanced materials have been created for the

military. And now there is an impetus to try their application in civil infrastructure.

So, a team approach is very important. And a systemic approach, where we have to confront all of these problems simultaneously, the political ones, the code problems and so on. And we have not been doing that, I think. We have been——

Senator GREGG. Is there a forum that brings together Federal Highway, the State commissioners——

Dr. BORDOGNA. We are starting——

Senator GREGG [continuing]. The academics, the, you know, industrial leaders and——

Dr. BORDOGNA. I think that is beginning. There are several now. Harvey Bernstein here is from the Civil Engineering Research Foundation, which is relatively new, and attempts this kind of operation.

Mr. BERNSTEIN. If I could just expand on that, my testimony today will probably address some of the questions that have been raised.

In particular, in the highway area, our role at CERF is actually to coordinate Government, industry, and academe across the entire civil engineering sector trying to move research results into practice.

And in the highway area, working with Federal Highways, AASHTO, the American Association of State Highway Officials, the Transportation Research Board, the Army Corps of Engineers, and other groups, we have actually organized what we call HITEC, the Highway Innovative Technology Evaluation Center.

HITEC is all geared toward trying to expedite moving highway innovation into practice. The big problem that we are really facing is the issue that even a company like DuPont or anyone else that has the technology and innovation that is ready to be used, cannot have it adopted on the State highway system simply because it is ready.

It has to be evaluated. It has to be accepted. For example, the State of California evaluates it, puts it through its evaluation system and then accepts it. The State of Nevada, Arizona, and the rest perhaps may not accept it.

Every company, every entrepreneur, every innovator must market his product to all 50 States. And each of the individual State criteria is often different. That makes it very difficult for anyone other than major companies to underwrite the costs associated with introducing innovative technologies.

Senator GREGG. That is not——

Mr. BERNSTEIN [continuing]. And money to do that.

Senator GREGG [continuing]. The Interstate System; right?

If it is going to be used on the Interstate System, is that also true?

Mr. BERNSTEIN. Well, it is true on the Interstate Systems. And it also flows down in terms of State and local and county systems. They have all of the problems associated with State and local ordinances.

Everyone feels that it has got to evaluated by them and their staff in order to justify its use. One of the reasons for creating HITEC was to try and set up a national process for new innovative

products where no standards exist—and, therefore, there are no really hard-fixed rules for it—so that HITEC can get it evaluated and adopted, in a process where we bring together all of the players.

That means having people from AASHTO and the States, local governments, Federal agencies, attorneys, insurance underwriters, all participating in the evaluation process. So, when it gets done, they feel a sense of ownership and a willingness to accept the results.

We already have agreement from the States through AASHTO that in setting up HITEC, this evaluation center, this national center and clearinghouse, that all are willing to take a look at and accept the results and recommend a quicker adoption in practice than on a State-by-State basis.

Part of my written testimony and attached documents specifically outline how that process works. It is all geared toward trying to set up a new system to work around the current system in order to get innovation out into practice.

Senator ROCKEFELLER. Maybe we should return to your testimony, since you are next up.

Mr. BERNSTEIN. OK.

Dr. BORLESKE. May I make one point——

Senator ROCKEFELLER. Yes.

Dr. BORLESKE [continuing]. And spend a few minutes to talk about a consortium that we actually have in action in the civil engineering?

Senator ROCKEFELLER. Yes.

Dr. BORLESKE. We have formed a group of universities, material suppliers, engineering and construction firms, along with the end user, the Department of Transportation, and are now in a consortium to build an all-composites bridge in San Diego, CA.

Our vision is to build a bridge, but the real value of this project is pulling again this complete value chain of people together. We will be drawing NIST in and other organizations to complete the partnership, to deal with the codes, the restrictions, and what have you.

And while we will build the bridge, the real advantage of this consortium is we are in there working together to develop an advanced materials technology package that can be applied to other new construction projects, as well as retrofit and repair.

In this consortium, we have the University of California at San Diego as the leader. We have DuPont, Hercules, BP Chemical as material suppliers and fabricator. We have Lockheed Missiles and Space as a high-technology space integrator company.

And we have J. Muller International, a world-renowned bridge design and construction firm, and then several small firms that bring in nondestructive testing and modeling capabilities. And we are adding several other firms to round out our competencies.

Right now, the catalyst for this consortium is the Department of Transportation with the $1.6 million grant to us. We are looking at the defense reinvestment package as sources for other support for this program. We will be working with NSF. We will be working with NIST.

The important thing is that each company is putting a significant amount of their own money into this partnership. Our program is a 4-year program. And we hope that we will have a very lasting effects.

So, really, in summary of my testimony, I really would like to leave you with, I think, some points that are well in your mind right now.

The Government does have a very significant role in this area. For many of these technologies, you are the customer. You need to practice the good business practices to make sure that these technologies get to the market very quickly.

You are also very important as far as the enabler and organizations like ARPA, organizations like NIST. The Advanced Technology Program, the manufacturing programs at NIST are all very important in helping get the advanced materials to the marketplace quicker.

Thank you.

[The prepared statement of Dr. Borleske follows:]

PREPARED STATEMENT OF DR. STEPHEN G. BORLESKE

Senator Rockefeller, Distinguished Members of the Subcommittee, my name is Stephen G. Borleske; I work for DuPont as a new business development manager in the Advanced Material Systems business. DuPont manufactures a variety of high performance fibers, polymers and ceramics and is also engaged in manufacturing composite parts and systems from these and other advanced materials. We serve both defense and civilian markets employing over 10,000 people in high tech, quality jobs. I am also an active participant in industry trade associations—The Suppliers of Advanced Composites Materials Association (SACMA) and the United States Advanced Ceramics Association (USACA)—and societies—The Federation of Materials Societies (FMS) and Society for Advancement of Material and Process Engineering (SAMPE). Last year I had the honor to serve as the SAMPE Congressional Fellow on the House Committee on Science, Space and Technology; I was privileged to participate actively in the national debate on industrial policy which was the foundation for much of the current effort on America's Global Competitiveness. I am honored to testify at your hearing on Advanced Materials in Infrastructure Modernization.

THREE KEY POINTS

Through my testimony today, I would like to establish three points with the Subcommittee:

1. The best way to create new, high-quality jobs, spur growth in the national economy and solve some of our pressing societal needs is to speed the commercialization of U.S. advanced technologies. The Government must serve as a stimulus to adoption of advanced technologies, not just invention.

2. Our nation's infrastructure, which is so vital to our standard of living and global competitiveness, is aging and needs improving. Advanced materials and systems technologies have the potential to contribute significantly to solving our nation's infrastructure problems, but these technologies will not be commercialized in the current traditional, fragmented construction business environment.

3. The Federal government, through DOT, DOE, GSA and other agencies, is the "influential first customer" for infrastructure improvements. In cooperation with industry, government must use modern business practices to accelerate the development and commercialization of advanced technologies such as advanced materials and systems. Sponsoring joint industry, government, academe demonstration and insertion projects focused on a strong market need is one of the key vehicles to do this. In addition to the role as the customer, government is also the enabler through organizations such as ARPA, MST and NSF.

Let me develop these points by describing several different elements, such as 1) advanced materials and the industry status; 2) the infrastructure problem and the construction industry from a material suppliers perspective; 3) industry, govern-

ment, academe infrastructure partnerships in action, with emphasis on what DuPont is doing; and 4) finally some specific recommendations for this Subcommittee.

ADVANCED MATERIALS AND THE INDUSTRY STATUS

Advanced materials are polymers, ceramics, metals or mixtures thereof that because of their unique chemistry or structure have unique properties such as much higher strength, stiffness, temperature and chemical stability than commonly used metals, wood or plastics. We think of them as space age materials that allow us to land a man on the moon or build high performance military equipment. Today we are beginning to recognize that many of the same properties of high strength, stiffness and corrosion resistance may also have high value when used in down-to-earth applications in bridges, cars or sewer pipes.

The advanced materials technology has been designated as one of our national critical technologies important in both military and civilian competitiveness. Potentially, by the turn of the century, markets for advanced materials represent a $400 billion global market opportunity and 1.5 million "high skill" jobs for American workers, but only if market pull exists to draw these technologies into continuous use. The industry was-developed in the 70's and 80's on the promise of very profitable markets in the defense and aircraft aerospace industries. For the most part, the key initial customer for these products was government. Today both of these markets are strongly depressed and many of the quality jobs in this industry are at risk.

Over the past year, the industry has been working aggressively together through the trade associations and societies to develop an industry perspective on the problem and potential solutions. These are summarized in two reports: "The Advanced Materials Agenda for the Clinton Administration and the 103rd Congress" (SACMA/USACA March, 1993); and the "Materials Industries' Strategic Needs for the 21ST Century" (FMS, Sept., 1993), which I ask permission to have added to the record of this hearing. The key strategy to make this industry prosper is to commercialize advanced materials and systems technologies in a range of civilian markets including transportation, communications, environment and infrastructure. The industry is ready to do its part.

OUR NATION'S INFRASTRUCTURE PROBLEMS AND THE CONSTRUCTION INDUSTRY

The problem of America's decaying infrastructure is well known. The Office of Technology Assessment (OTA) described the needs well in its report: "Delivering the Goods: Public Works Technologies, Management, and Finance" (April, 1991). According to OTA, Government has $1.4 trillion invested in public infrastructure and spends $140 billion annually to renew, rebuild and expand this investment. Each year taxpayers will pay billions of dollars due to the lack of materials durability, construction methods that disrupt the public use of the facilities for long periods of time, and the ever increasing maintenance requirements.

The reward for bringing new technology to the infrastructure business is of national scale. The Transportation Research Board, for example, has calculated that improving the durability of America's roads and bridges by one percent would cave the nation at least $10 billion and potentially $30 billion over a 20-year period. With that kind of a financial carrot, the logical question to ask is why aren't America's materials and construction industries aggressively pursuing new products and processes? The answer is straight forward: no one company can afford the risk to bring innovation to this industry.

In sharp contrast to other industries, the construction industry is very fragmented, with over one million firms. The consequence of this fragmentation is a fiscal inability of an individual firm to conduct the research and development necessary to create innovative materials and processes. In addition there are many barriers in the form of codes, regulations, and specifications that stifle rapid commercialization of new products and encourage the continued use of existing antiquated technologies. In this environment, potential suppliers of innovative materials technology, like DuPont, cannot individually afford the risks. Very imply put, while the public need is well documented and promising technological capabilities exist, American industry in the current environment cannot afford to do business in this market.

BRIDGING THE GAP THROUGH INDUSTRY/GOVERNMENT/ACADEME PARTNERSHIPS

The solution to this problem is to apply sound quality business management principles to speed the commercialization of new technology into the marketplace. A fundamental approach is to identify the customer and each of the major participants of the business value chain and have them work collectively to solve the problem

for the benefit of all involved. This process, pioneered in Japan, is the basis for much of the business revolution that is going on in well-managed companies throughout this country. In the infrastructure market, the government (state, local and federal) is the key customer that defines the need, establishes the specifications (codes, regulations) and pays the bill. Other participants are the engineering and construction firms that design and build the structures, materials suppliers and fabricators and various technology sources, primarily the university community.

The construction industry is different from many other industrial sectors in that much of the research and development capability lies in the academic community. NSF currently supports the science and engineering base for innovation in civil infrastructure. The academic community and the NSF programs therefore must be a key part of bringing new technology to the marketplace.

DUPONT INFRASTRUCTURE PARTNERSHIPS

Policy statements from many diverse organizations urge the Congress to create industry, government, academe partnerships to enhance America's competitiveness. The good news is that many companies, including DuPont, are not only talking but also doing. I would like to share two specific partnerships that I am involved in for DuPont. Both are focused on getting.DuPont advanced materials and systems into the infrastructure market.

The first is the effort of the Civil Engineering Research Foundation (CERF) to bring together the construction industry, diverse material suppliers and fabricators, appropriate government organizations (both users and enablers) and the academic community to develop a High Performance Construction Materials and Systems Plan for America and its Infrastructure. Since you will be hearing testimony from CERF later today, I will not comment on this program other than to raise strong support for this effort.

The second effort is a consortium of Universities, the composite materials and manufacturing industry and the civil engineering and construction industry to transfer the advanced composite technology primarily developed and applied in the defense industry to the civil sector, commonly known as ACTT. The vision that drives this consortium is a demonstration/ insertion project to build a composites cable-stayed bridge over Interstate 5 in San Diego, California, joining the two campuses of the University of California, San Diego. The current participants are the University of California with its world-renown Powell structures testing laboratory leading the consortium; DuPont, Hercules, and BP Chemicals (Hitco) as material suppliers and fabricators; Lockheed Missiles and Space Co., a leading defense systems integration company; J. Muller International, a world class bridge design, engineering and construction firm; and two small companies, X-Rays Technologies and Trans-Science, supplying nondestructive testing and modeling capabilities. We are in the process of adding additional members to round out our competencies.

While the focus of the consortium is the San Diego bridge, the consortium members recognize that the broader benefit will be the development of an advanced materials technology package that will have broad utility to both new construction and retrofit and repair. Through the use of composite materials we are working to extend service life, reduce construction and maintenance costs, and improve performance—especially seismic integrity and corrosion resistance. The development of cost effective manufacturing processes is a key thrust of this partnership. The program is funded initially by a $1.6 million grant from the Department of Transportation, who we view along with the California Department of Transportation (CALTRANS), as the customer for this technology. The four year research, development, and application program the consortium is pursuing will have a total cost, including the construction of the bridge, of approximately $55 million. The consortium is seeking federal support from several programs including DOT, ARPA, NSF and NIST. In addition to federal funds, each of the consortium partners is investing heavily in this project. The consortium has only been in existence for several months, and we are already learning from each other. While it is a challenging experience for a diverse group of industry, academe and government to work together, all the members of ACTT are convinced that we will make more progress commercializing composites technologies in the civil infrastructure market working together, rather than working separately.

Recommendations:

Before going into some specific recommendations, I would like to reiterate two key points:

1. The Government must serve as a stimulus to the adoption of advanced material systems and other advanced technologies in both the defense and civilian sectors. This is essential for America's global competitiveness.

2. The Government should become the "influential first" customer for advanced material systems in areas of key societal needs such as the infrastructure area. This will bring solutions of higher value to the tax payer, increase jobs, as well as boost the competitiveness of the industry.

Specifically I would like to recommend:

- Continue to create and fund technology demonstration and insertion programs like the bridge project. Increase the funding for ARPA, the NIST Advanced Technology Program, and the user agencies like DOT, DOE and others.
- Use organizations like ARPA and the NIST Advanced Technology and Manufacturing Programs to develop the enabling capabilities like manufacturing technologies, but include market focus by ensuring that user agencies like DOT, DOE,GSA and others participate in defining customer needs and commercialization barriers.
- Leverage the buying power of the government by requiring some portion of the purchase specifications include technology innovation.
- Continue to drive towards a realigned, focused and coherent technology policy that is based on strong industry, academe and government input such as you are hearing from the participants of the materials and construction industries. The goal is to accelerate the utilization of advanced material systems technology for commercial purposes.

Again, thank you for the opportunity to present these views to the Subcommittee.

Senator ROCKEFELLER. Thank you.

Harvey Bernstein, who has already been called on, is president of the Civil Engineering Research Foundation here in Washington, DC. And we welcome your testimony.

All of your testimony is a part of the record automatically so that you do not need to give it all if you want to summarize it.

STATEMENT OF HARVEY M. BERNSTEIN, PRESIDENT, CIVIL ENGINEERING RESEARCH FOUNDATION

Mr. BERNSTEIN. Thank you, Mr. Chairman, Senator Gregg, members of the subcommittee.

I think it is appropriate to point out that one of the reasons that the Civil Engineering Research Foundation is here, and was created, was to fill this void of trying to bring all of the parties together within the same room, because design and construction is such a fragmented industry.

Just to set the stage and give you a little background, the Civil Engineering Research Foundation is an affiliate of the American Society of Civil Engineers, known as ASCE, which is the oldest national engineering society in the United States and numbers over 110,000 members.

CERF was established in 1989, by ASCE specifically to facilitate, coordinate, and integrate applied research for the civil engineering profession and the design and construction industry which represents approximately 8 percent of the gross domestic product.

Our mission is to minimize duplication of research efforts, to leverage the limited research funds that are available to perform large-scale cooperative R&D, and to expedite the transfer of research into practice.

In our short history, CERF has succeeded in bringing together Government and corporate leaders from the design and construction industry, through our Corporate Advisory Board, and in uniting more than 50 diverse industry associations through our National Council for Civil Engineering Research, which is known as NCCER.

NCCER represents almost 500,000 individuals, some 100,000 firms, and numerous State and Federal agencies. Our potential total outreach is in the millions.

Through these linkages, and through specific industry initiatives that I will address, CERF has focused on developing a broadbased national consensus designed to meet America's growing technological needs and to successfully respond to the global challenges facing our Nation.

Mr. Chairman, in the interests of time, I use this opportunity to summarize my written remarks rather than go through all of them.

First, let me set the stage by briefly defining our national needs. In the February 1993 seminal paper "Technology for America's Economic Growth, a New Direction to Build Economic Strength," President Clinton and Vice President Gore concluded that the United States must move from supporting basic science and mission-oriented research to helping private firms develop and profit from innovations.

As part of its action plan, "A New Direction" promotes the rebuilding and maintenance of a world-class transportation system and Federal investment in advanced technologies in order to facilitate their commercialization.

In order to define our national civil infrastructure R&D needs, we must be cognizant of global actions that impact on U.S. business. In 1990, CERF led a delegation to Japan to study Japanese construction R&D efforts.

What we learned was that the Japanese stress participatory cooperation, that their government's long-range vision is the driving force behind R&D, and that application of R&D results are encouraged through government policies, procurement methods, and industry practices. These observations, I might add, are documented in this report "Transferring Research Into Practice: Lessons From Japan's Construction Industry," which I submitted with my testimony.

Our national civil engineering research-related needs are many and clearly exceed the fiscal capacity to be resolved all at once. Recognizing this, CERF conducted a national research needs forum in 1991, and published a report entitled "Setting a National Research Agenda for the Civil Engineering Profession," which I have submitted to you with this testimony.

From this agenda report and the Japan report, CERF concludes that the most important path to fundamental change is a long-term focus on programs that promise lasting positive impacts.

CERF and the National Science Foundation have just, in the last week, completed a benchmark analysis of the scope and thrust of civil engineering-related research in the United States.

I have submitted to you a copy of some of the preliminary results of this survey, and I might point out it is preliminary, but it does give comparisons internationally, and it does give some data on U.S. investment in R&D in each of our major sectors.

We estimate from this survey that the total public and private expenditures for civil engineering infrastructural-related R&D exceeded $2.1 billion in 1992, of which approximately 60 percent was funded by the Federal sector.

Further, only about 16 percent of the total, or about $342 million per year, is invested in construction materials research. Surprisingly, construction materials are not currently included in the Federal Advanced Materials and Processing Program, known as AMPP, a program under the White House Office of Science and Technology Policy that was funded in fiscal year 1992 at $1.66 billion.

Senator ROCKEFELLER. And when you say not included, do you mean it is just——

Mr. BERNSTEIN. Construction materials are not part of that program.

Senator ROCKEFELLER. It is just not on the list.

Mr. BERNSTEIN. It is not on the list.

Senator ROCKEFELLER. Even though we are talking about a critical technology.

Mr. BERNSTEIN. That is correct. We are working right now with the Office of Science and Technology Policy to try and make sure that in future years the construction materials which are critical to our nation's——

Senator ROCKEFELLER. Do they have to go through a process to get it on the list, or can Jack Gibbons or somebody just write it in and say, "There it is"?

Mr. BERNSTEIN. I am not sure.

Senator ROCKEFELLER. Could you find that out for us?

Mr. BERNSTEIN. Do you know that?

Dr. BORDOGNA. Yes. I think it is getting on the list already. The process is very malleable to input from industry like Harvey is giving. I have been at meetings in which they have talked about the problem of construction materials. So, I think there is receptivity.

Senator ROCKEFELLER. You said "receptivity."

Dr. BORDOGNA. From my understanding, it is on the list. There is an interest in construction materials for bridges, highways, and so on. It has not been focused on in the past, and I think Harvey is correct here, because our Government had been interpreting advanced technology to mean high-technology, semiconductor electronics, and so on. I think "high-technology" construction materials are now of great interest.

Senator ROCKEFELLER. Well, what was the whole point of the stimulus package? Granted it did not pass, but——

Dr. BORDOGNA. Sure. And I think that is what changing. So, I think there is a change going on.

Senator ROCKEFELLER. You think it is now on the list?

Dr. Bordogna. Oh, yes.

Dr. BORLESKE. I would concur with that. It is making the list, and there is a very definite effort to bring industry together with Government officials to develop plans for construction materials. In fact, I leave this hearing to go to one of those meetings out at NISC this afternoon.

Senator ROCKEFELLER. Mr. Bernstein, I do not mean to keep interrupting.

Mr. BERNSTEIN. No. That is OK. It is very appropriate. In fact, in a couple of minutes here I will specifically make a recommendation tied to where the emphasis should be placed on those construction materials.

Just to finalize setting the stage on our needs, a fundamental challenge in the United States is the uncoordinated nature of construction materials R&D. This arises from many factors, chief among them, the fragmented nature of the entire construction industry.

Unlike the other major components of our economy, the construction sector, which is the second largest piece of our economic mosaic, is dominated by small firms, individually incapable of significant research and development.

Moreover, it is a sector inhibited by many hurdles that make commercialization and even demonstration projects an enormous challenge for both large and small companies.

I am pleased to mention today, though, that the lack of coordination, the shortage of funding, and the inability to commercialize high-performance construction materials R&D, is now being addressed and resolved through a partnership between the public sector, the construction sector, and academia.

For the past 2 years, CERF has coordinated an industry-driven planning committee, involving experts from both the public and private sectors. The result is a proposed national program which is synopsized in CERF's most recent publication, "High Performance Construction Materials and Systems: An Essential Program for America and its Infrastructure."

This program was addressed to the President and members of Congress as a way of introducing a 10-year program estimated at about $2 billion, with matching funds from industry, to try and bring about a shift in focus on construction materials as we look toward the future.

Senator ROCKEFELLER. I have a quick question. As I remember my visit to West Virginia University, and the composite materials that would replace highway cement, I suppose one could logically conclude that the cement industry, were this to be introduced, would disappear, or at least in become smaller.

Mr. BERNSTEIN. No. In fact, what is unique about this study, and the companion documents that lay out all the programs, when we started this effort, the natural problem we had was that the concrete industry was looking out for what made the most sense for the concrete industry, and the steel industry, and likewise.

Each material had something to contribute to our national needs, but each one needed to be able to have an opportunity to voice their concerns, and our role was to coordinate all that, and get it into the national program.

This represents all materials, concrete, steel, composites, plastics, timber. In fact, the meeting that Steve is going to this afternoon is one of the many committees set up as part of this program.

We are working with the various groups within the construction materials sector to organize detailed plans. This second volume is the first document which really lays out a detailed plan for the concrete and steel industries.

By the end of this year, we will have companion documents on composites, timber, aluminum, and other major materials. The whole purpose is to get them working together for what is best for the Nation, and try to move away from their own particular orientation.

Senator ROCKEFELLER. You will have a battle plan, but you will not have solved any of the so-called hurdles that Dr. Borleske was talking about, the State codes, and this, and that.

Mr. BERNSTEIN. Actually, we do have a solution for that. It is actually being implemented. In the second half of my oral remarks——

Senator ROCKEFELLER. If I let you get to them. [Laughter.]

Dr. BORLESKE. I might add that each organization that is working to put these plans together is dealing with the barriers. So, at each step, I am working with the advanced composites group, we are dealing with what are the barriers to getting these materials into the market.

Senator ROCKEFELLER. Let me ask all four of you then, and then I promise I will absolutely shut up until all four or you finish talking.

According to what the three of you have said, can you say to me, because of what you are now doing in these collective efforts that by the end of the next 2 or 3 years that these obstacles, whether at the Federal level or the State level, that the impediment to the advanced materials being used in construction by reason of being shut out by codes or other federally or State-created situations will have disappeared?

Mr. BERNSTEIN. No. In 2 or 3 years it definitely would not disappear. It is a slow process. But I think we are moving collectively to start to reduce some of those barriers——

Senator ROCKEFELLER. Why is it a slow process? I mean——

Mr. BERNSTEIN. There are approximately 40,000 State and local highway jurisdictions in the United States.

Senator ROCKEFELLER. I can remember when I was a Governor, these huge construction companies would come in, and would pour miles and miles of interstate through the mountains of West Virginia, which is very expensive to do, and then our State engineers would go and inspect, and they would find that the bubble content in the cement, very infrequently, of course, was too high.

And then at cost to the company, at total cost to the company, they would have to go and completely redo all of that section of cement, presumably at enormous costs to them.

Now, you are talking about difficulties of States, and codes, and Federal impediments, and all this. I mean what bigger motivation could there be than cement that has too many bubbles?

I am just talking not with an academic background, but just from having observed and have actually been on one of those bubbly pieces of cement, which could not pass mustard, because we said it could not.

Dr. BORLESKE. Senator, we need leadership. We need leadership from people like yourself to stand up and say, "We will change the system."

Senator ROCKEFELLER. Who is fighting the system?

Dr. BORLESKE. Nobody is fighting for the system. Nobody is fighting for a new system, where we are integrated.

Senator ROCKEFELLER. But if I let him finish, he is.

Dr. BORLESKE. We need your help.

Senator ROCKEFELLER. OK. Let me let you finish talking.

Mr. BERNSTEIN. I think you are right on target. You are picking up on some of the critical things that we see. And I think with your help and other members of Congress, we are right on that edge right now, where I think there are some critical things happening.

I think you will hear also from Dr. Bordogna in a little while that the coordination between CERF, NSF, and the industry, in trying to get all of the Federal agencies working together with all of the major players in industry, is really bringing about some critical shifts that I think are resulting in these coordinated programs.

As I mentioned, this program envisions a 10-year research and development effort, encompassing traditional and emerging construction materials. The 10-year program requires a minimum investment of approximately $100 million in Federal funds, which could be tied into the FCCSET Program, which would be matched by the private sector in the form of both funding and in-kind support.

And our private industry has indicated that they are ready to make that commitment. This, I submit, is a small investment, given its potential for enormous returns.

Let me cite an example from this executive report, just on the potential that the change in materials can offer. Today's typical concrete compressive strength is 4,000 or 5,000 pounds per square inch, or PSI. Improving this strength by just a factor of two or three, say, 15,000 PSI, will significantly reduce the volume of concrete required, and afford new design possibilities.

Even at relatively low strengths, impressive results have already been achieved. For example, a 1987 Federal Highway Administration study using 10,000 PSI concrete calculated that for a 150-foot bridge, the number of supporting girders could be reduced from nine to four.

In France, an experimental bridge using only 8,700 PSI concrete required 30 percent less concrete. That means less cost, and from my way of thinking, less cost there means we can do a lot more with the same money for more infrastructural rebuilding.

Senator ROCKEFELLER. So, I am thinking now of the Chelyan Bridge in southern Chelyan, WV, which is old and needs to be replaced. It does not, like the French one, have nine——

Mr. BERNSTEIN. Girders.

Senator ROCKEFELLER [continuing]. Girders. But let us pretend for the moment that it did. Back 10 years ago, when we were talking about replacing it, it was going to cost $36 million. That was for a complete replacement. Let us say it is now $60 million, because of inflation. What would that bridge, under these new circumstances, advanced materials, less girders, probably cost instead of $60 million?

Mr. BERNSTEIN. I would like to tell you $40 million, but the reality of it is that until we have the technique accepted and used, even though you may be using less material, you may end up spending more time in some of the design and the application, just because it would be one of the first ones.

Senator ROCKEFELLER. Particularly in the beginning.

Mr. BERNSTEIN. Right. But ultimately there are estimates of hundreds of millions of dollars in savings. We have made estimates, and so have other groups, that with high-performance mate-

rials being introduced, savings could range to 15 percent of construction each year. So, that is substantial. If you look at——

Senator ROCKEFELLER. And that is just the construction of it. The maintenance of the bridge——

Mr. BERNSTEIN. Right. Maintenance costs, life cycle costs, we are talking about possibly doubling the life cycle, and reducing maintenance costs. All of this implies significant savings to any State.

The big problem is, at least as far as cost, looking at life cycle costs.

Senator ROCKEFELLER. Yes. OK. Thank you.

Mr. BERNSTEIN. In order to ensure that this program will actually succeed, and that we can bring about the cooperation of all involved, CERF is in the process of establishing what we are calling a national coordinating council, to be known as NCC.

NCC will be a coordinating body for all national materials programs. As such, NCC will have diverse representation from all material sector suppliers and fabricators, the construction industry, academia, and the public agencies.

Liaison with the White House Federal Coordinating Council on Science, Engineering, and Technology, which we know as FCCSET, is being maintained in order to facilitate the desired and necessary participation of key Federal agencies in this national program.

This includes coordination with other significant initiatives, such as the Civil Infrastructure System, CIS program, of the National Science Foundation, which Joe will discuss in a little while, and the work of the National Institute of Standards and Technology.

Now, the success of the high-performance construction materials and systems program, and other national programs, is contingent on overcoming the barriers which inhibit the transfer of U.S. technology, materials, and systems into the marketplace, which is the very question you are asking.

In order to help expedite the commercialization of U.S. products, CERF, in cooperation with Federal and State governments, industry, and academia, is creating what we call innovative technology evaluation centers, known as ITECs, for highways, buildings, and environmental technologies.

ITEC's utilize a consensus process, patterned after some of our experiences in Japan, involving all interested parties, including adversarial entities, in order to overcome barriers early in the commercialization process, not after the fact, but up front. And as Steve mentioned, we are addressing those problems before the program gets implemented.

Our goal is to minimize the time and costs associated with introducing new technologies into the marketplace, while providing a higher level of comprehensiveness and reliability in the evaluation process.

Let me briefly describe one of these centers, the Highway Innovative Technology Evaluation Center, known as HITEC. HITEC's goal is to become a nationally recognized service center and clearinghouse for implementing highway innovation.

Last September, Congressman Norman Mineta helped CERF launch HITEC at a national workshop. He said:

> The challenge is fusing together the innovations we need to build a new world of tomorrow, a world in which well-built highways link up easily with transit, and

transit links up with airports, and airports link up with freight ways. Efforts like CERF's HITEC will make that possible.

HITEC will serve as a focal point for evaluating new highway products, materials, and processes, and help to expedite transfer into practice. By providing impartial evaluations of technologies, where no industry standards exist, it is anticipated that HITEC will enhance the incentives for private industry to invest in highway-oriented research and development, and for State and local governments to be able to implement the innovative products immediately into the highway system.

This program is fully supported by the Federal Highway Administration, the Army Corps of Engineers, the Transportation Research Board, the American Association of State Highway and Transportation officials, and the American Society of Civil Engineers.

Jane Garvey, the new Deputy Administrator of the Federal Highway Administration, enthusiastically endorsed HITEC, and stated:

HITEC is the key to restarting the engine of renovation. It is a wonderful way to expedite the implementation of new technology into our highway system. Although an enormous undertaking, HITEC is crucial to the future of the highways.

Details on how HITEC will operate are contained in an article in this recent issue of Construction Business Review, which is probably the best summary on HITEC. We have enclosed that as well.

I might add one aside to my presentation, before I conclude, Mr. Chairman. I opened my testimony with mention of CERF's factfinding trip to Japan in 1990.

Next week, CERF, in conjunction with the National Science Foundation, will lead a national delegation of 30 corporate executives, along with key individuals from Federal and State governments, and the academic community, to seven countries in Western Europe.

The task force will examine the state of the art of Western European constructed civil infrastructure systems and materials, future technology trends in Europe, and the processes used in Europe to expedite the transfer of research into practice.

This European trip will be documented in a report similar to the Japan report. I would be happy to brief members of the subcommittee on the results of our meetings in Europe upon my return.

In summary, the administration and the design construction industry, through CERF, have suggested that national programs and needs can be solved through coordinated, cooperative national programs that integrate the expertise and resources of industry, the public sector, and academia.

I urge you to support these efforts, such as the Innovative Technology Evaluation Centers, and the High-Performance Construction Materials and Systems Program. In particular, if we as a Nation are really serious about reducing the costs of infrastructure modernization and maintenance, then you must support and fund the initiatives I have described today, in order to ensure their successful implementation.

The potential benefits of this program are, in fact, the basis for our long-term prosperity. We have the opportunity and the challenge of making a wise investment for our next generation.

Mr. Chairman, the Civil Engineering Research Foundation greatly appreciates being given this opportunity to present the views and convictions of the civil engineering professionals on whom this Nation must depend to make our twenty-first century infrastructure a reality.

I hope my comments and the additional information I place into the record will be helpful to you and the subcommittee.

In conclusion, let me state that CERF willingly offers its services to you and the Nation to serve as coordinator, facilitator, and integrator for any national civil engineering-related infrastructure R&D efforts. This concludes my remarks, and I will be happy to respond to any other questions.

[The prepared statement of Mr. Bernstein follows:]

PREPARED STATEMENT OF HARVEY M. BERNSTEIN

INTRODUCTION

Mr. Chairman and members of the Subcommittee, my name is Harvey M. Bernstein, President of CERF, the Civil Engineering Research Foundation, which is the research affiliate of ASCE, the American Society of Civil Engineers. ASCE is the oldest national engineering society in the United States, and today numbers over 110,000 members. CERF was established in 1989 by ASCE to "facilitate, coordinate, and integrate" applied research for the civil engineering profession and the design and construction industry, which represents nearly 9 percent of America's Gross Domestic Product (GDP). CERF's mission is to minimize duplication of research efforts, leverage the limited research funds available to perform large scale cooperative R&D, and to expedite the transfer of research into commercial practice. In summary, CERF is transforming a fragmented industry approach to R&D into coordinated national programs that will ultimately improve U.S. industry business performance, and our global competitiveness.

In its short history, CERF has succeeded in bringing together government and corporate leaders from the design and construction industry through our Corporate Advisory Board (CAB), and in uniting more than 50 diverse industry associations through our National Council for Civil Engineering Research (NCCER). NCCER represents almost 500,000 individuals, some 100,000 firms, and numerous state and federal agencies. Our potential total outreach is in the millions! Through these linkages, and through specific industry initiatives that I will address, CERF has successfully focused on developing a broad based national consensus designed to meet America's growing technological needs and to successfully respond to the global challenges facing our nation.

OVERVIEW

Mr. Chairman, in my testimony today, I am going to discuss several essential issues; these issues are so important and so fundamental that I will begin by noting them now:

- first, the quality of our constructed infrastructure has a fundamental impact on our economic efficiency, our global competitiveness and our general well being. We can't afford to enter the 21st century in blissful ignorance of these facts. We must act now to develop truly high performance construction materials, both traditional materials such as concrete and steel, and those advanced materials of special interest to this subcommittee, such as composites and ceramics.
- second, we are already expending significant dollars on materials related research; what is lacking, however, is the focus, the coordination, the "critical mass" of a nationally coordinated program, targeting agreed upon national needs.
- third, even minor advances in material technology, if successfully transferred into practice, will produce savings many times greater than cost.
- fourth, the design and construction industry is ready and eager to join in an historic partnership with the federal government. Working in unison, the public and private sector can accomplish what neither is likely to accomplish alone.

Mr. Chairman, before I begin, let me set the stage by first defining our national needs.

DEFINING NATIONAL NEEDS

In their February 1993 seminal paper "Technology for America's Economic Growth, A New Direction To Build Economic Strength", President Clinton and Vice President Gore boldly outlined their agenda for expediting the development of private sector technology. Their program, A New Direction, recognizes that technology plays the critical role in stimulating and sustaining long term economic growth, and that in order to build economic strength and spur economic growth, the U.S. must move from supporting basic science and mission oriented research to helping private firms develop and profit from innovations. Further, the paper recognizes that new growth industries are "knowledge based" and depend upon continuous generation of new technological innovations and rapid commercialization, and that "cooperative research is a powerful way to get technology and know-how into the hands of businesses that are in a position to put them quickly to work." As part of its action plan, A New Direction promotes the rebuilding and maintenance of a world class transportation system and federal investment in advanced technologies in order to facilitate their commercialization.

When defining our national needs, we must also be cognizant of global actions that impact on U.S. business. In 1990, CERF led a delegation to Japan to study the Japanese construction R&D efforts. What we learned, in a nutshell, was that the Japanese stress participatory cooperation, their government's long range vision is the driving force for R&D, and that application of R&D results are encouraged through government policies, procurement methods, and industry practices. These observations are documented in CERF's report entitled "Transferring Research Into Practice: Lessons from Japan's Construction Industry," which is submitted with this testimony, and form the basis for some of my comments.

Our national civil engineering research-related needs are many, and clearly exceed the fiscal capacity to be resolved at once. It is therefore critical that we address, first, those national needs that, in turn, help resolve other national needs. In 1991, CERF conducted a National Research Needs Forum and published a report entitled Setting a National Research Agenda for the Civil Engineering Profession, which I have submitted to you with this testimony. What is unique about this report is that it is a nonpartisan compilation of national research needs resulting from the cooperative effort of over 300 leaders from government, industry, and academia.

From this report, and the Japan report, CERF concludes that the most important path to fundamental change is a long-term focus on programs that promise lasting positive impacts.

Consistent with that finding, CERF, in conjunction with the U.S. Army Corps of Engineers, is in the process of identifying dominant public works infrastructure system needs at the state and local levels and will prioritize those needs. We are examining infrastructure related technologies developed within our federal laboratory system to determine which ones offer potential solutions for identified public works needs. CERF and the Corps will then consider the market potential of these technologies, identify potential manufacturers, develop optimal funding strategies, and recommend appropriate technologies for demonstration projects. This will provide private industry with an opportunity to piggy-back onto federal R&D investment, which should lead to the commercialization of new products and the creation of new enterprises.

Public and private investment in infrastructure related R&D is already substantial; CERF and the National Science Foundation have just, in the last week, completed a "benchmark" analysis of the scope and thrust of such research (a copy of some preliminary results entitled "Nationwide Survey of Civil Engineering R&D" is included with my testimony). We estimate that total public and private expenditures for civil engineering/infrastructure related research and development exceeded $2.1 billion in 1992; of this sum, approximately $1.3 billion was funded within the federal sector. While substantial, I should note that this $2.1 billion is a very small percentage of overall national R&D expenditures; for example, it is only 2.9 percent of the estimated current federal annual R&D funding of approximately $73 billion.

Total U.S. construction materials research is a small component of total civil engineering-related R&D, estimated at 16.3 percent, or $342 million per year. To put this into perspective, federal funding for construction materials research is only about $122 million of this annual investment of $342 million. Moreover, construction materials are not currently included in the federal Advanced Materials and Processing program (AMP), a program under the White House Office of Science and Technology Policy that was funded at approximately $1.66 billion in FY 92.

Further, and again consistent with the Administration's views on technology, the survey highlights the important role of the federal government in research and how

a basic reorientation of federal R&D can have enormous impact on successful technology transfer and commercialization.

A fundamental challenge in the U.S. is the un-coordinated nature of construction materials R&D. This arises from many factors, chief among them the fragmented nature of the construction industry! Unlike the other major components of our economy, the construction sector, the second largest piece of our economic mosaic, is dominated by small firms, individually incapable of significant research and development. Moreover, it is a sector inhibited by many hurdles, hurdles that make commercialization and even demonstration projects an enormous challenge for both large and small companies. An excellent example are project delivery systems that stifle and, too often, preclude innovation.

Another example is the pervasive focus on initial cost instead of life cycle costs of an infrastructure component which is a prescription for a non-durable, intensive maintenance facility, and an added burden on future generations, to say nothing about the impact on efficiency and global competitiveness.

COOPERATIVE NATIONAL PROGRAM ON HIGH-PERFORMANCE CONSTRUCTION MATERIALS

I am pleased to mention today that these deficiencies have been recognized and a solution proposed, a solution that creates an historic "partnership" between the public sector, the construction sector and academe. For the past two years CERF has coordinated an industry-driven planning committee involving experts from both the public and private sectors. The result is a proposed national program which is synopsized in CERF's most recent publication: "High-Performance Construction Materials: An Essential Program for America and its Infrastructure," a copy of which I ask be added to the record.

The impetus for this program emerged during the 1991 National Civil Engineering Research Needs Forum I mentioned earlier. The program envisions a ten-year research and development effort, encompassing traditional and emerging construction materials, with initial focus on concrete and steel because of the preponderant role of these materials in today's construction industry, where more than 500 million tons of concrete (two tons per person) and 30 million tons of steel are produced annually in the U.S. for construction activities.

I would like to emphasize one aspect of this program. The projected cost, when compared to other national initiatives, is modest. The ten year program requires a minimum investment of approximately $100 million per year in federal funds, to be matched by the private sector in the form of both funding and in-kind support. This I submit, is a small investment given its potential for enormous returns.

Is the ten year minimum public-private cost justified? Mr. Chairman, the evidence is compelling! Let me cite two examples from the Executive Report. Today's typical concrete compressive strength is 4,000-5,000 pounds per square inch (psi); improving this strength by a factor of two or three (15,000 psi, for example) will significantly reduce the volume of concrete required and afford new design possibilities. Even at relatively low strengths, impressive results have already been achieved. For example, a 1987 Federal Highway Administration study, using 10,000 psi concrete, calculated that for a 150 foot bridge, the number of supporting girders could be reduced from nine to four. In France, an experimental bridge using only 8,700 psi concrete required 30 percent less concrete. In a similar vein, the Transportation Research Board (TRB) has calculated that improving the durability of America's roads and bridges by one percent would save at least $10 billion, and potentially, $30 billion over a twenty year period.

To successfully implement this program requires a truly coordinated effort. The basis for such coordination has already been developed by the joint efforts of the construction sector, the federal agencies and academe, and is outlined in the Executive Report. Liaison with the Presidential Initiative on Advanced Materials and Processing of the Federal Coordinating Council on Science, Engineering and Technology (FCCSET) has been developed and is being maintained in order to facilitate the desired and necessary participation of key federal agencies in this national program. At the heart of this program is a National Coordinating Council or NCC, to be organized and staffed by CERF, whose tasks and responsibilities include:

- helping develop and promote nationally coordinated infrastructure materials programs.
- promoting total program objectives through proactive interaction and consortium building with national policy makers, user groups, funding sources, infrastructure oriented industries and associations, and the general populace.
- serving as a neutral integrator and coordinator between government, industry, and academe and as a neutral program voice in public and private fora.

- identifying and addressing the hurdles or barriers to successful commercialization and demonstration of high performance materials.
- coordinating/overseeing demonstration projects and commercialization.

I have already cited a fundamental problem of the construction sector, namely its fragmented nature. Instead of a small number of large firms, such as is true for automotive, aerospace and others, we have a legacy of over one million firms.

In spite of this, however, I can tell you that the construction sector is ready and willing to undertake this national effort, in order to improve the industry and enhance the nation's constructed infrastructure. This effort transcends the capability of the industry alone; congressional support is therefore critical and essential if truly high-performance construction materials are to become a reality. In this context I would also stress the fact that the construction industry looks forward to working not only through this proposed national program but also to effective coordination, cooperation and interaction with other significant initiatives such as the Civil Infrastructure Systems (CIS) program of the National Science Foundation (NSF) and the work of the National Institute of Standards and Technology (MST), including the Advanced Technology Program.

COOPERATIVE NATIONAL PROGRAMS TO EXPEDITE RESEARCH INTO PRACTICE

It is a fact, repeated time after time, that American innovation ends up being implemented elsewhere and exported to its birthplace! We must collectively remove the barriers that now stifle innovation in the United States. Cooperative national programs can do this for one compelling reason: the scope of the problems and needs we face are far beyond the capability of the private sector alone, government alone, or academe alone.

CERF is already working through this tri-partite coalition to create national programs to help expedite the transfer of research and innovation into practice. I already described our national program on High Performance Construction Materials, I would now like to briefly describe our national efforts on the creation of Innovative Technology Evaluation Centers or ITEC's.

What CERF is creating in cooperation with federal and state governments, industry, and academia is a "consensus process" targeted to find ways to expedite the commercialization of civil engineering-related technology. Our goal is to minimize the time and cost associated with introducing new technologies into the marketplace. At the same time, we need to provide a higher level of comprehensiveness and reliability in the evaluation process. The objectives of the ITEC's are as follows:

- to enhance the incentive for private industry to invest in R&D.
- to improve opportunities for bringing new technologies into the marketplace in a timely and cost effective manner.
- to provide prompt, efficient, and effective nationally recognized evaluations.
- to provide one stop impartial screening and evaluations of private sector technologies for use in federal, state, and local construction.
- to serve as a clearinghouse for civil engineering-related technologies.
- to save substantial time and expense for state and local agencies and industry innovators, while providing an equal or higher level of comprehensiveness, reliability and consistency than can be provided through agency-by-agency evaluations.

HIGHWAY INNOVATIVE TECHNOLOGY EVALUATION CENTER (HITEC)

Let me briefly explain one of the centers. Under a multi-year cooperative agreement with the Federal Highway Administration, and in close coordination with the many facets of the highway and civil engineering community, CERF is in the process of establishing the Highway Innovative Technology Evaluation Center (HITEC). HITEC's goal is to become a nationally recognized service center and clearinghouse for implementing highway innovation.

This past September, Congressman Norman Y. Mineta (D-CA) helped CERF launch this new center at a national Workshop on Implementing Innovative Highway Technology which was organized by CERF, FHWA, TRB, and AASHTO. The Congressman said the "challenge is fusing together the innovations we need to build [a] new world of tomorrow * * * a world in which well-built highways link up easily with transit, and transit links up with airports, and airports link up with freightways * * * efforts like CERF's [HITEC] will make that possible."

HITEC will serve as a focal point for evaluating new technologies (products, materials and processes) and help to expedite their transfer into practice. By providing impartial evaluations of technologies where no industry standards exist, it is anticipated that HITEC will enhance the incentives for private industry to invest in highway oriented research and development and for state and local governments to implement innovative products in the highway system. HITEC is fully supported by

the FHWA, COE, TRB, AASHTO, and ASCE. Jane Garvey, the new Deputy Administrator of the Federal Highway Administration enthusiastically endorsed HITEC and noted that "HITEC is the key to restarting the engine of innovation. It is a wonderful way to expedite the implementation of new technology into our highway system. Although an enormous undertaking, HITEC is crucial to the future of our highways."

Successful technology transfer demands new organizational concepts - many of which are already incorporated in HITEC such as a "consensus based approach," "pooled funding mechanisms," and value added service. HITEC will not be a specifier or a standards approval agency. Likewise, HITEC has no plans to develop a large staff or its own testing facilities; rather, it will utilize existing facilities and limit its role to that of "coordinator, facilitator, and integrator". Details on how HYEC will operate are contained in the article "Investing In Infrastructure: Putting New Innovations and Technologies Into Practice" in the May/June issue of Construction Business Review a copy of which is attached.

Innovative methods, products and services will have fewer roadblocks to overcome on their way to the marketplace and risks for participating organizations will be substantially reduced because of HITEC. This should lead to new market opportunities, new U.S. products and services, new businesses, and more U.S. jobs. Because of the national need, and the interests generated by industry in HITEC, CERF has already initiated planning with government, industry, and academia on establishing innovative technology evaluation centers for buildings and environmental technologies. We expect to hold national workshops in 1994 to get input on establishing BITEC (buildings technologies) and EITEC (environmental technologies).

I might add one aside to my presentation, Mr. Chairman. I opened my testimony with mention of CERF's fact finding trip to Japan in 1990. Next week, CERF, in conjunction with the NSF, will lead a national delegation of 30 corporate executives, along with key individuals from federal and state governments and the academic community to seven countries in Western Europe. This task force will examine the state-of-the-art of Western European Constructed Civil Infrastructure Systems (CCIS), future technology trends, the processes used to expedite the transfer of research into practice (which includes contract delivery systems), and a perception of what impact a united European Community will have on the U.S. design and construction industry. This European trip will be documented in a report similar to the Japan Report which is included with this testimony. A copy of a recent press release on the European trip is also attached.

SUMMARY

The Administration and the design and construction industry, through CERF, have suggested to you that national problems and needs can be solved through coordinated, cooperative national programs that integrate the expertise and resources of industry, the public sector, and academia. I urge you to support efforts such as the High-Performance Construction Materials program, and the Innovative Technology Evaluation Centers I described today. The costs associated with these efforts, while not insubstantial, are minuscule when compared to other federal programs. The potential benefits, however, far exceed costs, and are, in fact, the basis for our long-term prosperity. We have the opportunity and the challenge of making a wise investment for the next generation.

It's time to shift paradigms; time to implement new ideas and methods which differ from the norm; and time to remove barriers to innovation in the U.S. which are stifling the creativity of our industry, and thus limiting our opportunities to stimulate the economy. We must begin working together to create an environment more conducive to innovation; one that moves away from adversarial relationships and promotes cooperation.

Mr. Chairman, the Civil Engineering Research Foundation greatly appreciates being given this opportunity to present the views and convictions of the civil engineering professionals on whom this nation must depend to make our 21st century infrastructure a reality. I hope my comments and the additional information I have placed into the record will be helpful to you and the Subcommittee. In closing, let me state unequivocally that CERF is the realization of a new paradigm as regards technology and commercialization. The industry and the Administration share this vision and CERF willingly offers it services as "coordinator, facilitator, and integrator" for any national effort. This concludes my remarks. I would be pleased to respond to any questions you may have.

["Setting a National Research Agenda for the Civil Engineering Profession" and "Transferring Research Into Practice: Lessons From Japan's Construction Industry"

by the Civil Engineering Research Foundation may be found in the committee's files.]

Senator ROCKEFELLER. Dr. Julio Davalos is now a professor in the Department of Civil Engineering at West Virginia University. I am obviously particularly pleased that you are here, sir, and welcome your testimony.

STATEMENT OF DR. JULIO DAVALOS, PROFESSOR, WEST VIRGINIA UNIVERSITY, DEPARTMENT OF CIVIL ENGINEERING

Dr. DAVALOS. Thank you very much, sir. What I intend to do is to use some slides to show you the main points that I would like to make. I will be talking about mainly advanced composites used in the civil infrastructure. We are well aware that billions of dollars will be needed to rehabilitate our infrastructure.

Some critical examples of that, that I would like to point out, is that about 40 percent of the bridges in this country need rehabilitation. Another example that perhaps is not as well known to you, we use 12 million timber ties every year, at a cost of $500 million per year. So, obviously, we have to do something about these problems. We believe that advanced composites have a place to alleviate the infrastructure problem of our country.

The advantages of advanced composites are that they can be used in a very efficient way in such areas as corrosion, where it can be used as a reinforcement for concrete, cooling towers, and bridge decks.

The initial slides that I am going to show illustrate that advanced composites are already there, and they are being used for large structures. This slide shows the use of fiber-reinforced plastic bars in lieu of the steel bars that we typically use for reinforcement of concrete.

Cooling towers that are seen right outside of my office. These cooling towers are built entirely of composites. They have been in the market for about 10 years. It is a success story, in which it has been able to compete very, very well with traditional products such as concrete and wood.

This is a larger scale cooling tower for industrial applications, where large components of fiber-reinforced composites have been used for this project. All of the components, except for the foundation, are all made of fiber-reinforced composites. A very large-scale type of construction.

Senator ROCKEFELLER. Where is that?

Dr. DAVALOS. Dr. Barbero.

Dr. BARBERO. It is in Texas.

Senator ROCKEFELLER. Texas. OK.

Dr. DAVALOS. Also, the applications of composites are being sought in bridges. This is a small bridge. Obviously, this is in the incipient state. The applications in this particular area are not very extensive yet.

There are other advantages of advanced composites. They provide higher strength either by themselves or in combination with other products.

I mentioned earlier that we use about 12 million timber ties every year. Well, one concept that can be used to improve this

problem is that a timber tie can be encased in a fiber-reinforced composite shell to improve the durability of this product.

Senator ROCKEFELLER. In other words, you treat the wood, or do you just surround the wood with the composite?

Dr. DAVALOS. We would probably treat the wood, also. This is just an idea.

Senator ROCKEFELLER. OK.

Dr. DAVALOS. We need to develop this product in cooperation with industry. This can permit reuse of the 12 million timber ties that are treated chemically and have to be disposed of. So, we may be able to rehabilitate those ties and be able to encase them in a composite shell, and provide longer life and service for this product.

Another advantage of composites that is being tapped today, and perhaps it is one of the other reasons why they have been quite successful in the applications, is that they do not interfere with electromagnetics, and so it can be used for high-speed trains, for computer manufacturing buildings, and antenna enclosures.

This slide illustrates, although it is not very clear, the larger scale framed structures that have been built to enclose electronics and computers in the inside, for AT&T.

Senator ROCKEFELLER. I am sorry. Is that the roof of a house? What am I looking at?

Dr. DAVALOS. It is a whole building. You have an A-frame. It is what we call an A-frame in here. So, it is a series of frames built entirely of fiber-reinforced composites.

Senator BURNS. Doctor, I have a question here.

Dr. DAVALOS. Yes.

Senator BURNS. Will this situation, with your rafters—I assume your rafters there are the composite-coated lumber.

Dr. DAVALOS. No. Composite. It is all composite. There is no timber in this structure.

Senator BURNS. There is no timber at all.

Dr. DAVALOS. There is no timber at all.

Senator BURNS. OK.

Dr. DAVALOS. It is an all-composite structure. It is a specialized building that was built to house some electronics in the inside, because composites are quite inert. So, that is the reason why composites were chosen for this application. It is all composites.

Senator BURNS. OK. Now, you were showing us some ties a while ago.

Dr. DAVALOS. Yes, Senator.

Senator BURNS. Was this the railroad?

Dr. DAVALOS. Yes.

Senator BURNS. I am sorry. I had to leave, and I want to apologize. When you put that composite on the outside of the tie, it increases the strength; is that right?

Dr. DAVALOS. Yes, it does.

Senator BURNS. In a building like that, can you place composite on top for building materials?

Dr. DAVALOS. Certainly. We are exploring about the possibility. For example, earlier, it was mentioned that high-strength concretes can provide longer life, and that it can bring some cost reductions.

Well, high-strength concretes can provide even better service if they are reinforced with a composite, because when you confine

concrete, the strength and the ultimate failure mode is very, very high. So, there is a way to combine advanced composites with conventional products, such as concrete and wood.

Senator ROCKEFELLER. Well, now I am confused. You were talking about timber, and then you mentioned that that timber could be injected with the polymers or something to strengthen it, or it might not be. And then it is surrounded by composites.

Now, you are talking about reinforced cement, and then you talked about further reinforcing cement by the use of what, what is the next word, "composites."

Dr. DAVALOS. Well, yes.

Senator ROCKEFELLER. I was at West Virginia University 6, or 7, or 8 years ago. I remember it, because I was so excited by this, Senator Burns.

I was so excited by this, that I called a huge conference in West Virginia on advanced materials, and I had a conference. And I heard exactly the same thing that Dr. Borleske said, that this could be the world's largest world industry. Nothing has happened since my meeting 7 or 8 years ago.

I did nothing. Talk about leadership. I did nothing. Industry did nothing. The university has not caused anything that comes to my head. My question is, what I remember was that it was not cement we were talking about in this so-called concrete. It was a composite material. There was no concrete, there was no cement in it. It was a composite material.

In my mind at least, there was the vision of something quite different than cement, which would be laid on our Nation's highways, which would last, as they were telling me, more or less forever, you know, for 50 years, but there was no cement in it. It was entirely a composite. Now, help me understand.

Dr. DAVALOS. Such products have been developed in the market for pipe applications, and others. But I do not know about this particular product, and I apologize, at that time, when you visited the school——

Senator ROCKEFELLER. You were not there.

Dr. DAVALOS [continuing]. I was not part of it yet. So, I am not sure exactly what this product was. But one of the points that I am going to highlight it in my presentation today, I hope, is that things are changing, that a partnership approach to product development is emerging, and I was very glad to hear the two previous speakers that they addressed this particular issue. The team approach can bring the product into the industry, into the use of the public.

We have been very successful on a number of projects at West Virginia, which include our timber program. Fifty-six bridges, which are so-called experimental bridges, have been built in our State, out of 120 of these modern timber bridges in the whole United States.

That is because we have been able to work very closely with the department of transportation of the State, with industry, and with academia. If you take this approach, it is possible to put a product out there.

This slide is continuing my presentation. The two towers of this building here are built entirely of fiber-reinforced composites for communications services.

Now, I guess the question to ask is: Well, if these composites have been used so successfully in these slides that I have shown, why is it that a widespread use of composites is not in place?

Well, to a certain degree, it is in place. All the products that I have shown have been developed by what we would like to call small companies, $10 to $50 million companies.

They have evolved through a trial-and-error process, and they have been very successful at securing a small portion of the market, because of the electromagnetic features, because of their light weight, or for some specific application.

The problem is that most of the products that this industry is producing today are relatively small for the larger scale type of structures that we built. We feel that they do not possess the resources to develop the technology and the market for construction.

Now, looking at the picture for the large companies, the large companies we refer to as the aerospace companies, they certainly are seeking applications in the construction industry. They have the expertise.

They have been developing these composites for the last 50-plus years. They are quite experienced in the development of certain products and putting them out there. We feel that the resources of these companies are quite adequate, but the failure is the complexity of the civil construction companies, the civil construction industry. They will have to come to an understanding of how things are done in the civil construction industry.

The next two slides that I will present will give an illustration of that point.

Senator ROCKEFELLER. May I ask a question? What the others have been saying is that small companies do not have the capacity to put this out in the marketplace, and the implication was that larger companies, as you say, aerospace-size industry, would, and yet you are saying they have a lack of understanding of the civil construction industry. I do not understand that. Is that because they——

Dr. DAVALOS. Let me clarify that point. The small industries have been able to secure markets for their products. They have been quite successful, and they appear to be, to some extent, happy with the return that they are getting.

Their short-term investment policies, and the small capacity of their plant, in our opinion, do not allow them to produce the large-scale members that are needed for structural application. We do not believe that those companies will be able to develop the market, the construction industry market. I do not think that they can tap into the market.

On the other hand, the larger scale type of companies, the aerospace companies, which are basically the new companies into this industry, they will have to catch up very quickly with how things are done in the construction industry, which is a very complex process. It is a diversified process.

Let me show the next two slides, and perhaps that will even clarify this point further. On this slide, I would like to emphasize that

in the aerospace-type industry, the development of a product is achieved under a single umbrella, that is, it is an in-house integrated process that they use.

They acquire the raw products, they manufacture them, they do the design, they assemble the parts and the structure, and they do testing and certification. Certification mainly is done by one or two agencies that are involved from the outside.

On the other hand, if you were to look at the civil construction industry, it is divided into a number of players. You have the material suppliers, the material manufacturers, the designers, and the builders.

Now, the way that this industry talks to each other, the way that they do business is through codes and standards. So, these codes and standards for fiber-reinforced composites are not in place, and that is one of the problems. You can now see that there is a big difference between the two approaches.

Well, what can we do about it? The first point that we proposed as a solution was brought earlier, and it is to develop a team approach, a consortium for research, development, and application.

But this cannot be created just as a global big picture. It has to have some specific goal. I was very glad to hear today that there is such a consortium, for example, to put a bridge in place. That is the kind of consortium that we think is going to work. It has to end with an end product, a demonstration project.

At West Virginia University we have tried this time and time again, and it works. It has to involve Government agencies, industry, and universities. But all the specific research questions have to be addressed under the big umbrella, which is the demonstration project.

And further, we should then take it a step forward and transfer this technology out there to the user, which then would lead to the development of codes and standards for the specific product.

The timber bridge program that we have at West Virginia University is a very good example. We have developed codes, designed methods, and so forth for the specific types of structures that were approved by AASHTO. So, perhaps that is the way to do it.

A second key point is the development of codes and standards. This is very fundamentally important in the civil construction industry. We believe that the market will follow the first standards that are available.

So, if the Asians or the Europeans come with the first standards for advanced materials, then we, as civil engineers, will have no choice but to follow them, and, therefore, those countries will lead this industry. So, these codes and standards serve to integrate the whole industry.

That is the picture that I presented to you earlier. We communicate among companies through codes. It promotes the standardization of products, which then leads to a reduction in costs.

It promotes public safety and confidence in the product, and it enables the construction companies to build. Without codes, they take some degree of risk, and the building can only be a demonstration project.

Finally, as a professor, I cannot help but to bring this issue, that education is needed. It is paramount. We are targeting these advanced composites to engineers, civil engineers.

Those are the guys who are going to carry this forward. Those are the guys who are going to push this, and yet, we do not teach advanced composite design to civil engineers in our current curriculum around the country.

Senator ROCKEFELLER. It is exactly like the fact, Senator Burns, that we do not teach preventive medicine——

Dr. DAVALOS. That is also true.

Senator ROCKEFELLER [continuing]. To our medical students. That is exactly what you are saying. We do not teach advanced composites; that is, preventive corrosion, deterioration for the future, in our civil engineering classes.

Dr. DAVALOS. Yes. Exactly.

Senator ROCKEFELLER. That is unforgivable, in both medical schools and civil engineering, it seems to me.

Dr. DAVALOS. Yes. We do have courses in timber design, steel design, concrete design, but there is no course on advanced composite design at the undergraduate level.

That concludes my presentation. I would just like to end by emphasizing that in the statement that we submitted to you, we show examples of how at West Virginia University, in West Virginia, we have been able to be very successful in taking the approaches that I presented here today, to bring the end- product to the users out there.

I would just like to mention that we also have a bridge, a reinforced concrete bridge, with fiber-reinforced plastics, that is going to be in place by the end of this year. So the testing and the evaluation of this bridge will then follow early next year.

Thank you so much.

[The prepared statement of Dr. Davalos follows:]

PREPARED STATEMENT OF DR. JULIO F. DAVALOS

The nation's civil infrastructure encompasses the industrial and public works that support our daily activities. Coastal and marine structures, bridges, parking garages, buildings, highways, sign posts, chemical and waste treatment plants, and many others are examples of infrastructure components, also called constructed facilities.

A recent workshop on Use of Composites in Construction (CFC, WVU 1992), concluded that "a high volume market for mass-produced, low-cost fiber-reinforced polymer matrix composites lies in the construction of highway structures, buildings, housing, railways, pipelines, power lines, marine structures and even as parts for automobiles and construction equipment." A recent estimate by the Society of the Plastic Industry (SPI 1992) shows that the Civil Engineering market will rely on the composite materials industry for about $135 million annually for marine construction, excluding bridges, buildings, and pipelines. The projected estimated market for these materials is about $90 billion dollars by the year 2000 (Federation of Materials Societies (OTA) 1988). The industry of fiber-reinforced polymer composites can be classified into two broad groups: (1) low-cost composites mass-produced in high-volumes, which constitute most of the composite structural shapes being used currently in civil structures, and (2) higher-cost composites produced by defense-oriented processing methods; these advanced composites are seeking applications in the construction industry. Recognized progress made in the use of composite materials over the last 50 years has shown the satisfactory performance of applications and has created new markets for innovative and high-technology components and systems. The growth rate of composite materials consumption is estimated to be about 15 percent per year, with a total forecast of about 200 million pounds by the year 2000 (OTA 1988). In contrast, 500 million tons of concrete and 24 million tons

of steel—out of a total of 80 million tons—is used annually in construction in the United States.

Fiber-reinforced polymer composites offer several advantages over conventional materials: light weight, which reduces transportation and building costs; high strength to weight ratio; excellent non corrosive, nonmagnetic, and damping properties; and low maintenance costs. In addition, composites can be engineered to satisfy high performance requirements for specific applications. However, a number of factors affect the widespread use of composites in civil infrastructure. The barriers to the commercialization of composites in construction are in part due to the following reasons: (1) The high-volume and low-cost composites industry, which produces most of the construction-type composite products being used today has been able to secure small markets for its products, but due to its relatively small operational capital and short-term investment policies, it may not be able to develop the market for large-scale load-bearing structural components needed in the civil infrastructure; (2)on the other hand, the defense-oriented composites industry, which is accustomed to an in-house integrated approach to prroduct development, faces the complexity of a diversified construction industry, which is compartmentalized into specialty industries such as material suppliers, manufacturers, designers, and builders; finally, (3) there is a lack of awareness of composite materials by the civil infrastructure engineering community. In this testimony, we discuss briefly the civil infrastructure needs and the role of composite materials; the primary barriers to commercialization of composites and the proposed strategies to overcome them. To illustrate the major points of this testimony on a team-approach to the commercialization and successful use of composite materials in civil structures, we provide an overview of the achievements in the area of composite materials by the CFC of West Virginia University. The exhibits attached to this testimony further illustrate the important points presented herein.

INFRASTRUCTURE NEEDS AND ROLE OF COMPOSITE MATERIALS

Recent studies estimate total needs of $3 trillion in the next ten years for the rehabilitation of our nation's infrastructure, and constructed facilities related to transportation needs alone will require $800 billion per year. As part of our nation's infrastructure deterioration, 230,000 of the 575,000 highway bridges are in need of repair or replacement, and about 143,000 of these 575,000 bridges are 50+ years old and unsuitable for current traffic demands. Over the next four years, the lost of productivity resulting from bad roads and bridges will cause a 3 percent decline in the GNP, and 8 percent increase in the Consumer Price Index, and over a 2 percent decline in employment. As another example, approximately 12 million railroad ties are replaced annually at a cost of $500 million dollars per year.

The versatility of composite materials and their favorable characteristics, such as high-strength and corrosion resistance, can be efficiently used to develop new long-lasting and durable components and systems for the nation's civil infrastructure. In addition, fiber-reinforced composite materials can be used as reinforcement for conventional materials, such as concrete and wood, to increase their performance. Moreover, composite materials can be utilized for rehabilitation of existing facilities. Composite materials have been shown to provide reliable performance in such applications as chemical and water-treatment plants, specialized buildings, antennae housings, and cooling towers.

ADVANTAGES OF ADVANCED COMPOSITES

The main advantages of composite materials for infrastructure applications are: corrosion resistance, light weight, electromagnetic transparency, and the possibility to tailor the material for specific applications.

Most of the nation's infrastructure is build with steel and concrete reinforced with steel bars. As steel corrodes, it expands and cracks the concrete. In turn, this cracking accelerates even further the corrosion of the reinforcing steel, and this interactive cycle leads to eventual structural failure. As an example, bridge decks may last only about a decade in regions where deicing salts are used in the winter. Replacing the steel bars by composite bars would eliminate the corrosion problem. While the idea is not new, only in the last few years there has been an improvement in the quality of the composite bars to make the application feasible. Research conducted at WVU has demonstrated the technical feasibility of using composites instead of steel to reinforce concrete.

The light weight and high strength of composites can be used to rehabilitate and improve existing structures. Many existing bridges are carrying higher than expected traffic loads, and the weight of the concrete bridge deck uses a significant portion of the useful load-carrying capacity of the structure. Moreover, many of

these concrete decks have to be replaced because of corrosion deterioration. Composite materials offer the possibility of replacing the deteriorated deck with a lightweight deck. In this way, the bridge could be re-rated for a higher load without significant changes to the foundation and supporting beams, both of which can be the most costly components of the bridge. The composite replacement deck would provide a longer service-life than a deck built with the same technology as the original one.

In addition to corrosion resistance and light weight, composites have unique properties that set them aside from conventional materials. Composite materials have been used extensively in applications where electromagnetic transparency is required. These applications include: supporting structures for imaging equipment in hospitals, antennae and antennae coverage amid high rise buildings, testing laboratories for computers and high voltage equipment. Furthermore, utilization of composite materials may be advantageous for the construction of the guideway of Magnetically Levitated Trains (MAGLEV).

Perhaps the main advantage of composite materials is the possibility of tailoring the properties of the material for specific applications. With conventional materials, the physical properties are virtually fixed. Composite materials are a combination of two or more materials. Therefore, the properties of the resulting composite can be altered significantly by changing the constituent materials, the proportion of each constituent material to the total, and the orientation of the reinforcing fibers.

A successful application of composite materials for infrastructures is ceramic cooling towers. Corrosion resistance is considered the main factor of the success of these all-composite, ceramic-filled, cooling towers. These towers carry the heavy load of the ceramic blocks used to refrigerate the water. Their corrosion resistance has resulted in lower maintenance cost than concrete or wood towers. The light weight of the towers reduces the foundation and structural cost of buildings where they are installed. For more than a decade, the all-composite cooling towers have been competing successfully in the marketplace with designs using conventional materials. The highly engineered composite material used in these towers compensates for the relatively higher raw material cost. The durability of these towers in a high temperature, humid environment ascertains the reliable performance of properly designed composite materials in harsh environments.

Structural composite members are increasingly used in mass transportation systems, such as MAGLEV. Although the main applications are currently on vehicles, composite structural shapes are being considered for the guideway systems as well. Low stiffness and high initial cost are the main deterrents of the application of composites to guideway structures. However, there is enough incentive to consider composites for guideway systems. Composites can be produced in modules that can be easily assembled and quickly replaced in case of deterioration. The flexibility of creating complex shapes with composites encourages the concept of developing multipurpose guideways that can carry various services, like communication fiber optic cables and power lines. The corrosion resistance of composites can result in more durable structures that can provide longer service-lives than conventional structures, and initial higher costs for composite structures may be justified if ongoing research can successfully quantify the expected life-cycle of composite materials.

BARRIERS TO COMMERCIALIZATION

Composites can be classified into low-cost and high-cost materials. Low-cost composites (about $1 to $2/lb) use glass fibers as the reinforcement and are produced by mass production techniques. High-cost composites (above $10/lb) use carbon and aramid fibers as the reinforcement and are produced by more expensive techniques required in aerospace applications. Both high- and low-cost composites may offer excellent performance, and thus, both are called advanced composites, to differentiate them from earlier reinforced plastics.

Low-cost composite materials have already made significant inroads in the infrastructure sector in applications such as antenna coverage, off-shore construction, water treatment plants, and others (see attached exhibits). Companies working in this area have been successful in securing markets where the advantages of their composite products, such as noncorrosive and nonmagnetic properties, exceed the low load-carrying capacity limitations of the components being offered. However, these products are not quite suitable for the large civil infrastructure market, where initial low cost and high performance are required to compete with conventional materials. Low-cost composite material producers are actively developing some markets, but their limited resources and short-term investment policies may not allow them to develop the technology for all of the promising infrastructure markets. For example, the Composite Institute of the Society of Plastics Industry has targeted

marine construction as their primary objective for market diversification; federal agencies, such as, the Federal Highway Administration, are promoting applications in the area of highway structures.

The low-cost composite structural shapes being produced today have similar geometries to those of steel and aluminum shapes. The current composite shapes do not provide the high stiffness usually required for adequate structural performance. However, new optimal composite shapes combined with innovative designs and/or conventional materials can overcome the low stiffness problem. Surprisingly, the civil engineering community appear to be more concerned with the ultimate (failure) strength, consistent properties, and reliability of composites than with low stiffness and other real or perceived deficiencies of low-cost composites.

The high-cost composites industry is searching for new applications, because of the decline of the military use of composites in recent years. Several attempts have been made at transferring composite technology developed for aerospace applications into the construction industry. This effort has proved to be more complex than initially expected due to various factors, including the low-cost and large-scale structural components needed in infrastructure applications.

There are fundamental differences between the aerospace and civil engineering industries. Aerospace and mechanical engineering design firms integrate all aspects of product development, from the material design and processing to the manufacturing and final product. In contrast, civil engineering firms design with standardized sections that can be assembled in a unique way to create a specific structure. Therefore, the civil construction philosophy and requirements are quite different from those of the aerospace industry. The integrated and concurrent design philosophy of the aerospace industry conflicts with the standardization required by the construction industry. However, aerospace industries have the expertise, technology, resources, and experience in product development required to advance the utilization of composites in construction.

The civil construction approach has several advantages that should not be underestimated. Standardization brings along significant cost reductions. It also allows for easier compliance with codes of practice, which are necessary to regulate the design of structures for public use. In this sense, standard prismatic sections have more advantages than disadvantages, and therefore, mass-production process, such as pultrusion, can allow aerospace-oriented composites industries to develop a market for large-scale structural shapes. This can be accomplished by combining the market experience developed by the low-cost composites manufacturers with the technology and the resources of the high-cost composites industry. The transition from conventional materials to composites would be easier for the construction industry if composites were produced in sections similar to their counterpart in steel. In fact, user acceptance guided the design of current composite structural shapes. However, care must be taken not to compromise the advantages of composites while trying to mimic existing steel structural shapes.

Fiber reinforced plastic composite structures have been around for forty years, mostly as showcases with limited applications in civil engineering construction. One of the reasons inhibiting the general use of composites in civil engineering construction is the lack of design manuals, codes, and standards. However, significant research, development, application, and in-situ testing efforts are still required to develop such design guidelines. Acceptance of composites by the civil construction industry depends to a large extent on the availability of design manuals, codes, and standards. Also, research efforts are required to show that the durability of composite structures indeed is longer than that of conventional structures.

STRATEGY FOR SUCCESS

Composites have significant advantages over conventional materials but show a significantly different behavior. Therefore, structural composite design and the conception of the standardized structural shapes must be undertaken with an open mind, in the sense that is must be accepted that the design of a structure with composites may lead to a concept that is significantly different from that which we are accustomed to see in conventional materials. Moreover, the main advantage of composites is the possibility to tailor the material to the specific application. Unlike the aerospace industry where each design is unique, tailoring of the material for each single stricture may not be possible in the construction industry because of the need for standardization. However, it must be realized that due to the large volumes of materials used in construction, tailoring for classes of structures should be possible. In fact, this has happened over the years for conventional materials, like steel and wood composites, where either the shapes or the stacking sequences have evolved

into some optimal configurations for classes of applications, such as columns, beams, etc.

To overcome the barriers to the commercialization of composites in the construction industry, we suggest that the following three key steps should be undertaken: (1) a team or consortia approach to concurrent research, development, and applications, leading to demonstration projects and technology transfer; (2) development of design codes and standards; and (3) development of an educational program in composites for civil engineering students and practitioners.

There is a need for an integrated approach to develop the market for composites in civil infrastructure. The advanced technology on composites available in the aerospace sector must be combined with the know-how of low-cost composites manufacturers that have already succeeded in securing some sectors of this market. Research capabilities of Engineering Schools on materials and structural systems must be tapped, and government efforts must be focused on rearch, development, and application (RD&A), with specific demonstration and technology transfer projects to conclude a program. Design and construction companies must participate from the beginning. Creation and support of consortia for RD&A in specific areas may be an alternative to integrate such diverse industries as raw material suppliers, composite material manufacturers, designers, and construction companies. Also, consensus by these organizations are needed to develop the codes of practice to be used by the various industries for the design, fabrication, construction, and performance monitoring process. The codes and standards serve to integrate the whole industry by acting as the communication channels among very diverse industries. Codes also promote standardization, which in turn results in lower costs. Furthermore, codes also serve to promote public safety and confidence.

Finally, an educational program for civil engineers must be developed. The success of composite materials in the civil infrastructure market hinges upon the understanding of these new materials by professional civil engineers that specify all materials used for construction. The education process must start immediately at the undergraduate level on schools across the nation. Moreover, short courses and informational publications for practicing engineers should be developed. Some preliminary programs are in place at some schools, such as WVU, and they may be used as models.

PROGRESS AT CFC-WVU

The CFC research, development, and project-demonstration efforts have been directed primarily to low-cost advanced composites for infrastructures. The five main areas of research, development, and applications related to fiber-reinforced composites are: (1) composite structural shapes, (2) reinforcement of concrete, (3) reinforcement of wood, (4) nondestructive testing and evaluation, and (5) technology transfer.

Current composite structural shapes mimic their steel counterpart. The main impediment for the widespread application of this materials is the lack of design guidelines and lack of property databases. The CFC has been actively involved in the characterization of the physical properties of structural shapes and the development of structural design guidelines for construction. Work has been performed in collaboration with the National Science Foundation, Federal Highway Administration, West Virginia Department of Highways, Federal Railroad Administration, and the Department of Defense. This program has active industry support from raw material suppliers and material manufacturers. Testing methods, design procedures, and performance data have been generated. The construction of a demonstration project is being pursued.

Reinforcement of concrete with composites is accomplished with glass fiber-reinforced bars that replace the conventional steel bars. Several agencies have participated in this effort. The most salient problems of the application of composite bars to reinforce concrete have either been investigated or are currently being addressed. Over the last five years, significant improvements have been made to the composite bars. These improvements have been achieved through active collaboration with the bar manufacturers. Laboratory testing results, that includes full size deck slabs for bridges, have shown excellent promise for this concept. The construction of a demonstration bridge deck for a primary road in West Virginia is planed for the near future.

Considerable effort has been directed towards the development and commercial implementation of hardwood composites and wood laminates reinforced with fiber-reinforced polymer composites. Recently, 45 large-scale laminated wood beams fabricated from Yellow-poplar, an abundant species in West Virginia (30 million cubic feet), have been characterized and tested. As part of a comprehensive program in this area, adhesive systems to bond composites to wood are being investigated. The

testing of large-scale Yellow-poplar beams reinforced with composites is underway. In addition, theoretical studies are being conducted for the integral production of wood-composite laminates by mass-produced processing techniques used in the composites industry.

Nondestructive testing (NDT) and evaluation (NDE) methods for composites are being researched at the CFC. As a result, several instruments have been built and patented, and other instruments are in the development stages. Since sensors can easily be embedded in composite materials, the NDT and NDE techniques being investigated at the CFC can be used to monitor the performance of composite structures.

Examples of the technology transfer efforts of the CFC in the area of composite materials include: (1) the Transportation Systems Rehabilitation and Maintenance Institute (TSRMI), cosponsored by the West Virginia Division of Highways and the Mid-Atlantic Universities Transportation Center; TSRMI is a graduate program that offers courses in composite materials to civil engineering students. (2) Workshops, conferences,' and short courses in composites for civil infrastructure applications. The exhibits attached to this testimony contain details of some of the CFC efforts listed here.

[“Structural Applications of Composites in Infrastructure,” by E. Barbero and H.V.S. GangaRao; and “Civil Infrastructure Systems Research: Strategic Issues,” by the National Science Foundation may be found in the committee's files.]

Senator ROCKEFELLER. Thank you, Dr. Davalos. Before I call on my friend at the National Science Foundation, are you four gentlemen saying that these codes—Senator Byrd and I have just been discussing this—that these codes and standards, which appear to be the enemy once you are trying to get the product out there, are at the Federal and State level as well as county, or are they in the engineering, AASHTO level?

Dr. DAVALOS. The minimum level is at the Federal level at which the——

Senator ROCKEFELLER. That is the worst level.

Dr. DAVALOS. That is the higher level at which these have to addressed and that is where the battles have to be fought. However, at the State level, depending on the State, some progress can be made. We are very fortunate to have a State that is very receptive to new ideas.

And so at the State level, the State of West Virginia has managed to take the risk and to trust the results that we have obtained through research that is not in a code form yet and to be able to allow us to build something.

And through this concession, then, a small door opened, so that the Federal agencies were able to look at these applications in a much more serious light.

Senator ROCKEFELLER. But on the other hand——

Dr. DAVALOS. Other States may not have the same attitude.

Senator ROCKEFELLER [continuing]. If the feds set the standards, the States would have no authority to supersede those, would they?

Mr. BERNSTEIN. Mr. Chairman, I might add a clarification on that. On the building side, you have what are considered—and I am not an expert on standards and codes, but yet, basically, three national uniform codes which have been adopted by various States, but each State and the local governments can and to amend the uniform code. But those three tend to drive a lot of the issues on the building side.

On the highway side, you, of course, have AASHTO setting a lot of standards, setting it from the State standpoint, which then flows down as well. And the third key is that there are two distinctions.

You have those for products where standards exist. They can move right in, if you design a new product that falls within certain guidelines or within a standard or code that can be applied: but, whenever we take a look at new innovation, a new product without a standard, the subject of risk and liability comes up.

And on the subject of risk and liability, in this society where litigations, our primary industry, all of a sudden you have a problem.

Senator ROCKEFELLER. We are going to change that in this session of Congress.

Mr. BERNSTEIN. I sure hope so. That, in itself, will open the door to everything else.

Senator ROCKEFELLER. That is interesting, is it not? In other words, if we pass product liability—no. Is that—would product liability, tort reform, would that make a major difference in this whole codes and standards business?

Mr. BERNSTEIN. It's one key element.

Senator ROCKEFELLER. We are going to pass that in the Senate this year. They are going to pass it in the House next year. And the President is going to sign it at the end of next year.

Mr. BERNSTEIN. If you can do that, that is terrific, because that will make a big difference. Another side of that is since the Government is the largest customer on most of these products, if the Government, through demonstration and evaluation programs, is willing to absorb a little of that risk, in partnership with the industry, we—by demonstrating those products and setting the standards through those demonstrations, with the Government as the customer, then there is a greater chance of getting the States and others to use it.

Usually, the question is: Well, who is going to use it first and whose risk is it? And so everyone looks the other way.

And the Government really has to make a decision that if it is going to procure certain materials, even under the basis of least-cost procurement. If some percentage of any procurement were to allow the introduction of new innovative materials without affecting the low-cost bids, it would open the door for innovation on the Federal side. Once a product is used some place and shown to work, it will be much more quickly adopted in standards to follow at the State and other levels.

Senator ROCKEFELLER. One further question from me: In the product liability bill which Senator Burns and I now are pushing, we say if something has been approved by the Federal Aviation Administration or by the Federal Drug Administration, that it cannot—that people cannot sue against it, in spite of injury.

Now, there are caveats to that. If any company has failed to tell the truth or has failed to update its information in any area, then the defense against punitive damages is waived, but you cannot go after punitive damages. And you cannot sue if FDA and FAA have approved it.

Now, what will we add on if we are going to affect the construction industry? What agency, Federal Highway?

Mr. BERNSTEIN. Federal Highway would definitely be one that would be involved.

Senator BURNS. What about if we made NIST more proactive?

Mr. BERNSTEIN. It would be a different role for NIST. I think——

Senator BURNS. I know it would be a different role, but I am telling you we are changing roles of traditional organizations anyway.

Mr. BERNSTEIN. I think any agency—and NIST is probably good. It is sort of neutral, because of technology and innovation across the board. The key thing is if you have an agency that is involved in checking on and evaluating the technology or processes and allowing them to be used on Federal projects, then once that is done, I think that could work across the board. That has got a lot of interesting potential.

Senator BURNS. I know—and Senator Rockefeller was probably not as much involved in this, but we have been involved in the dialog anyway of setting the standards.

You see, what I am afraid of is the same thing that the good doctor is afraid of is somebody else, our competitor starts setting standards and we have got no other choice.

We go along with that. And we end up using their material. It is like I said in my opening statement, I mean, we developed the VCR, but who is making it?

We should be in the business of setting the standards and codes for these new materials if we are going to be the, let us say, the big hog in the market.

We have been, for the last 4 years, trying to bring the electronics industries together to develop the standards and codes for high-density or high-definition television. This has been like pulling teeth to bring them together.

We are going to have to do the same things on the—whenever we start talking about the information highways, whenever we start talking about two-way interactive and broadband telecommunications, we are going to have to make sure that the intraoperability of the systems, whatever we build, can talk to one another.

So, it is not just in this industry of codes and standards in the building industry or the infrastructure of the concrete and the brick, so to speak. I am interested from a standpoint and I raised—my interest was greatly advanced whenever I see new things happening in the wood products industry, because wood products are very important to the State of Montana.

So, what I am saying is that this dialog is going to continue. I appreciate your comments very much, but I am just wondering does NIST, or whatever, do we retool somebody to get more proactive as far as codes and standards are concerned?

And you are right about that. Sometimes we have not—I am not real sure on these new materials, emerging technologies. It is going to have to be people like Senator Rockefeller and myself who will go to the annual meeting of our States' leagues of cities and towns and county associations, like MACO, Montana Association of Counties—and not just go and keynote their dinner, but be a participant in a working session.

When we do that, then we get attention. And it is just like I say, you know, we pass laws up here on the Hill. Our big downfall, as

legislators: We do not follow up on the rulemaking. They go down—sometimes some of the rules are made and they do not even look like the intention of the legislation. So, we have got to be more involved. So I appreciate that.

Thank you. I just kind of got off on that.

Senator ROCKEFELLER. No. That was good. That was right on line.

Dr. Joseph Bordogna, my apologies to you sir. You are the Assistant Director for Engineering at the National Science Foundation.

STATEMENT OF DR. JOSEPH BORDOGNA, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. BORDOGNA. Well, I am a member of the team. And I think what I have to say is a bit of a wrap up, but also to introduce some kind of "innovation-through-integration" notion here, because we have been hearing about this during the entire morning.

We have seen there is an urgent need to rebuild America. We have been talking about that, but the cost may be prohibitive if it is not done intelligently. And the burden of such an investment could jeopardize future U.S. economic growth.

Instead, the Nation must strive for coordinated intelligent renewal, a process that makes use of state-of-the-art research, to more effectively use our constrained economic material and human resources in a partnership between Government, industry, and academe.

Existing technologies in such areas as nondestructive evaluation, construction automation, high-strength materials and strategic management—we have alluded to these critical areas this morning—are currently being applied to this problem, but the growing complexity of the problem combined with constrained resources and the need to protect the environment, make it imperative that we develop new systemic knowledge and focus that knowledge in a systematic and integrated way.

What I would like to do today is describe a new research initiative in civil infrastructure "systems"—I am emphasizing that word—that can play an important role in synergizing much of what we have heard today in testimony by my colleagues.

This initiative, developed over the past 18 months, is a result of an extensive study conducted by a team of academic, industrial, and Government experts and with the help of professional groups like the Civil Engineering Research Foundation.

I am very pleased to provide you with a copy of the final report on infrastructure systems and strategic issues, along with the testimony.

The report proposes a bold new strategy that focuses on the optimal performance of systems, as well as the individual components, that is, looking at the opportunities before us in a holistic way. This is a tough challenge, because the Nation's infrastructure is made up of hundreds of large intricate engineering, political and economic systems that interact in complex ways.

Past research focused on the performance and operation of individual components in separate systems. The result is incremental improvement in some areas, with relatively unaffected systems per-

formance. In other words, the knowledge does not get spread across the whole Nation.

The new strategy requires systems integration at all levels and also addresses a need to develop and apply new scientific and engineering knowledge.

The national studies reveal that new knowledge is required in three key areas. I am not going to discuss these in detail in the testimony, but let me give you the gist of them: They are deterioration science, assessment technologies, and renewal engineering.

Deterioration science is a focus because we really do not understand why things deteriorate or fall apart. We make things like bridges and roads and so on. Everything is constructed, and the characteristics of the materials in the resulting structures change over time. We do not have a good handle on what is going on during the lifetime of these structures. So, the key issue here is to really spend the time investigating this area. We just coined the word "deterioration science" to lend focus to the work to be done.

Assessment technologies—here, again, we have an enormous amount of ability from the high-technology age to assess things. For example, why not throw a piece of concrete in an MRI machine like we put bodies in them? In fact, we have some work going on with researchers doing exactly this. And, indeed, you can see inside the material. We even could conceive of making new kinds of MRI machines; that is, tori, running up and down columns in buildings to check them out. This is but one example of the kind of yeasty look at how we might use high-technology for assessing infrastructure. Assessment, of course, requires bringing in political and economic notions, too; not just technological ones.

When you attack a system intellectually and say it needs to be repaired in some way, there are some new technologies which can have very serious application, like smart paint for example, something, which, when a hidden crack would develop inside the painted structure, the paint would rupture and a dye would be released to show you where the crack is.

There is also a use of modern fiber optics technology for infrastructure assessment. We know fiber optics are very important for transmitting our wide bandwidth high-speed information, but if we imbed these fiber bundles in materials, as we build structures or retrofit structures, we can have real-time assessment of what is going on with the structure, because the light properties of the bundles will change as the strain changes.

So, a lot can be done with assessment technologies in a grand way; that is, to focus on bringing the high-technology age of assessment to determine what has to be repaired.

Senator ROCKEFELLER. Can I interrupt again, because several of you mentioned glass fibers——

Dr. BORDOGNA. Glass fibers.

Senator ROCKEFELLER [continuing]. As reinforcing.

Dr. BORDOGNA. There are two aspects here. Glass fibers are excellent for reinforcing, but they are also——

Senator ROCKEFELLER. But how can they be?

Senator BURNS. He's saying——

Senator ROCKEFELLER. No. I am saying—but also the word "reinforcing," because you showed us buildings. How can—I mean, when I think of glass fibers, I think of, you know, little tiny noodles.

Dr. BORDOGNA. No. No. There are all kinds of glass. There is thick glass, thin glass, and varieties of glass that can be used for transmitting light or used for increasing structural strength.

Senator ROCKEFELLER. And if you just simply make them bigger, they have strength which is stronger than steel.

Dr. BORDOGNA. It is a simple way of looking at it. The point here is that materials have many different kinds of properties and are used in many different ways.

Senator ROCKEFELLER. Yes. So, I guess——

Dr. BORDOGNA. It is a material that does not corrode. And it has strength. It is a new way to mix a lot of materials to create a stronger structure. Glass also has a property that light can be transmitted through it. And when it gets strained in structure, the light transmission property will change, too. In this way, we can, in real time, monitor every second what is going on with the structure.

This is an example of what we mean by intelligent renewal, again—intelligent things. But, again, a big part of this is defense conversion again. There is an enormous amount of assessment equipment available and techniques we can bring to bear on the construction industry and civil infrastructure to good use. So it is a sharp focus.

The third area of interest is "renewal engineering." It has an aspect based on the fact that it is very hard to throw away $17 trillion of built infrastructure. We have to renew it.

There is a subtlety to this. We have trained our engineers for 40 years on designing something, building it, and tossing it or its parts away, replacing it, for example in a TV or radar set, with another circuit board or chip. Well, you cannot toss away the civil infrastructure. So, we need a whole new notion about how to renew, intelligently renew, infrastructure in all of its many dimensions.

These three areas of civil infrastructure systems—deterioration science, assessment technologies, renewal engineering—reflect the complexity, the multidisciplinary character of today's forefront research and illustrate the need to cooperate across fields of research and industries, across academe and industry, and across Federal and State governments to address national concerns.

For example, each of the areas address these focuses: cross cutting research in materials, mechanics, social sciences, geotechnical and structural engineering, fluid mechanics, water resources, sensing, control, environmental engineering, chemistry, mathematics, computer and information science, and so on.

It is also important to realize that the Nation has an important interest in earthquake engineering. This interest is coupled into the civil infrastructure systems program. This is not a separate effort off to the side, because much of what is being done in earthquake engineering can be applied to new infrastructure for seismic reasons and make renewal more doable and longer lasting.

To sum up, I wanted to give you an idea of what we are focusing on in research, but tied completely to what my colleagues have been talking about as needs in the marketplace. And it is also done

as a team effort. This study was done by an entire community working together.

In summary, this kind of integrated approach is required to overcome the significant barriers that exist in moving knowledge gained from research to practice.

That is why this new initiative in civil infrastructure systems involves a program to study and identify impediments to the transfer and implementation of research results.

That is sort of new in the last few years for Government-supported civil research, because we are not just going to do the research, but work concurrently to get it going out into the marketplace.

Such a program will address, for example, the fragmented nature of the infrastructure industry—you have heard about that today—identify public policy issues—we have talked about that today—and those legal and financial constraints which impede progress. And we also talked about that in the last few minutes.

Innovative nontraditional techniques will be required to link researchers and users, providing the mechanism for feedback to keep the research program aware of the critical issues.

Finally, I believe that science and engineering knowledge, if developed and used in a systematic and integrated way, can help our country build its civil infrastructure in the most intelligent and cost-effective manner.

A coordinated cross agency, CIS, Civil Infrastructure System's initiative, can help bring Government, industry, and academe together to work effectively to rebuild America. I want to emphasize that coordinated cross agency effort, because this morning we have talked again and again about how to get agencies to do things together—NIST, NSF, Highway, and so forth. And the plea I am making here and what we have in this program is to bring the talents of the agencies together in some way to get the job done.

The task is of vital importance to America. We all agree on that, but in addition to its critical relationship to transport, clean air and water, public health and commerce and fresh new wealth, which we desperately need in this country, the Nation's civil infrastructure contributes greatly to our self-image.

To paraphrase writer Cornell West, "The vitality of any public square ultimately depends on how much we care about the quality of our lives together."

Our public infrastructure reflects our economic policies and the pride we place on our common life.

Thanks very much.

[The prepared statement of Dr. Bordogna follows:]

PREPARED STATEMENT OF DR. JOSEPH BORDOGNA

Chairman Rockefeller, and members of the Subcommittee, thank you for the opportunity to testify on the efforts of the National Science Foundation to support research in the area of civil infrastructure.

Our Nation's economy, security, and quality of life depend on the vitality of its civil infrastructure. A society that neglects its physical infrastructure loses the ability to transport people, goods, energy and information, provide clean air and water, control disease, and conduct commerce. In the last 100 years or so the United States invested heavily in canals, harbors, water and sewage systems, highways, airports, rapid mass transit, electric power, and more recently in modern fiber optic information systems. But many of these sVstems have degraded due to age, neglect, misuse

and excessive demand. For example, the Federal Highway Administration reports that about 45 percent of the 575,000 highway bridges in the United States are functionally obsolete or structurally deficient.

There is an urgent need to rebuild America. But the cost may be prohibitive if this is not done intelligently, and the burden of such an investment could jeopardize future U.S. economic growth. Instead, the Nation must strive for intelligent renewal, a process that makes use of state-of-the-art research to more effectively use our limited economic, material, and human resources.

Existing technologies in such areas as non-destructive evaluation, construction automation, high-strength materials, analytical modeling, and strategic management, are currently being applied to this problem. But the growing complexity of the problem, combined with limited resources and the need to protect the environment, make it imperative that we develop new knowledge and focus that knowledge in a systematic and integrated way.

In his plan, "Technology for America's Economic Growth," President Clinton called for an integrated research program designed to enhance the performance and longevity of the Nation's infrastructure. We believe this call to action is both timely and critically important. By creating a national focus on civil infrastructure, we can stimulate not only creative public investment but the vigorous, industry-based investment critical to our national competitiveness and productivity. The impact on the private sector is not small. For example, construction is among the largest U.S. industries, making up 7.3 percent of the 1991 GNP and employing six million people. However, intense foreign competition, and inadequate investment in R&D, relative to Japan and Europe, are eroding the technological advantages of U.S. construction companies, causing our industry to lose ground in both the domestic and international markets.

NSF currently supports the knowledge base in science and engineering which makes possible many civil infrastructure innovations. For example, NSF currently provides 65 percent of the federal funding for basic civil engineering research, and has the lead agency role in earthquake engineering research. As an indication of its priority within the agency, in FYI 994 NSF is requesting $73 million for CIS-related research, which is an increase of $9 million or about 15 percent.

Today, I would like to describe NSF's new research initiative in Civil Infrastructure Systems (CIS) that can play an important role in realizing the President's vision. This initiative, developed over the past 18 months, is the result of an NSF extensive self-study and workshop conducted by academic, industrial and government experts, and with the help of professional societies, like the Civil Engineering Research Foundation (CERF). I am very pleased to provide you with a copy of the final report, Civil Infrastructure Systems Research: Strategic Issues, along with this testimony.

This report proposes a bold new strategy that focuses on the optimal performance of systems rather than the individual components. This is a tough challenge because the nation's infrastructure is made up of hundreds of large, intricate, engineering, political, and economic systems that interact in complex ways. Past research focuses on the performance and operation of individual components in separate systems. The result is incremental improvement in some areas but relatively unaffected systems performance. The new strategy requires systems integration at all levels and also addresses the need to develop and apply new scientific and engineering knowledge. Recent workshops have revealed that new knowledge is required in three key areas:

DETERIORATION SCIENCE

A fundamental issue in understanding why constructed facilities deteriorate is to better understand the science of the deterioration process. Most construction materials are dynamic and have properties which continually evolve over time. Any understanding of the deterioration process must be able to account for the entire spectrum of material characteristics and exposure conditions for the service life expected of the material. The objective is to understand better how to repair, renew, create, monitor and maintain structures that will last longer, be safer, and not adversely impact the environment. Major components of this research will be materials science, chemistry, mechanics, failure processes, risk and reliability.

ASSESSMENT TECHNOLOGIES

A major problem in repairing and upgrading infrastructure is an inability to assess accurately the state of health of a constructed facility. The sheer number of facilities to be evaluated and the difficulty of accessing vital structural components adds to the problem. Current methods for assessing constructed facilities are rel-

atively primitive and unreliable, prompting conservative, often costly decisions. Research in this area will focus on non-destructive evaluation of structures and systems, sensor technologies, characterization of performance under extreme events, acceptable risk assessment, interdependence of infrastructure systems; geographical information systems; and social and economic effects.

RENEWAL ENGINEERING

Constructed facilities need renewal, modification, and upgrading, and research will emphasize new design and construction methods. A research effort is needed to bring together cross-cutting technologies to develop innovative approaches involving material innovations, new designs, robotics and manufacturing technologies, innovative equipment, human factors and other supporting areas to improve productivity and quality in infrastructure and constructed facility problems. Other research topics include performance criteria and repair strategies, demolition, disposal, and recycling, and preservation of national resources.

These three strategic areas reflect the complexity and multidisciplinary character of today's forefront research and illustrate the need to cooperate across fields of research to address national concerns. For example, each of the areas address cross-cutting research in materials science, mechanics, social sciences, geotechnical and structural engineering, fluid mechanics and water resources, sensing and control, environmental engineering, chemistry, and mathematical, computer, and information science. Earthquake engineering research, which has helped to provide the existing engineering knowledge and human resources base, is an important component of the CIS Initiative. It addresses such issues as the development of better designs and materials for construction, and new approaches to increase the seismic safety of such infrastructure systems as bridges, highways, and utilities.

There is much evidence that such research, when appropriately applied, can result in large cost savings and efficiencies. For example, NSF-supported research at the University of Kansas on the bonding of reinforcing bars with concrete, resulted in the need for less reinforcement material, with potential annual savings of $100 million by the U.S. concrete construction industry. Another project at the University of California, Berkeley, developed an energy-absorbing, ductile steel device, which has the potential to save $100 million of the retrofit cost of the Bay Bridge for seismic safety.

In your own state of West Virginia, Mr. Chairman, NSF is supporting the work of Dr. Hota GangaRao, at the Constructed Facilities Center at West Virginia University. The work of Dr. GangaRao and his colleagues have led to innovations in advanced construction materials using glass fiber reinforcement, non-destructive testing and evaluation techniques, and development of self-monitoring "smart structures". The Center's activities are closely tied with practicing engineers, advanced materials manufacturers, and state transportation agencies.

This kind of integrated approach is required to overcome the significant barriers that exist to moving knowledge gained from research into practice. This is why our CIS Initiative involves a program to study and identify impediments to the transfer and implementation of research results. Such a program will address, for example, the fragmented nature of the infrastructure industry and identify public policy issues and those legal and financial constraints which impede progress. innovative, non-traditional techniques will be required to link researchers and users, providing a mechanism for feedback to keep the research program aware of the critical issues.

In summary, I believe that science and engineering knowledge, if developed and used in a systematic and integrated way, can help our country rebuild its civil infrastructure in the most intelligent and cost-effective manner. I also believe that NSF is well situated to play a catalytic role in making this happen. By creating a national focus for CIS education and research, the NSF initiative can lead to cooperative efforts with other relevant agencies and constituencies. Properly planned and executed, NSF's CIS initiative can help bring government, industry and academe together to work effectively to rebuild America.

This task is of vital importance to America. In addition to its critical relationship to transport, clean air and water, public health and commerce, the Nation's civil infrastructure contributes greatly to our "self image". To paraphrase writer Cornell West, "The vitality of any public square ultimately depends on how much we care about the quality of our lives together. Our public infrastructure reflects our economic policies and the priority we place on our common life." Thank you for the opportunity to appear before you today.

APPENDIX—NSF PROGRAMS IN CIVIL INFRASTRUCTURE SYSTEMS (CIS)-RELATED RESEARCH

DIRECTORATE FOR ENGINEERING (ENG). ENG-supported research enhances the knowledge base of and is most directly related to CIS. The topics currently supported include structural analysis and design, construction and fabrication, material processing and synthesis. power and communications, environmental engineering, and safety against earthquake, wind, and other hazards. ENG programs that support CIS research are: Structures, Geomechanics and Building Systems; Construction Processes; Mechanics and Materials; Earthquake Hazards Mitigation; Natural and Man-Made Hazard Mitigation; Fluid, Particulate and Hydraulic Systems; Environmental and Ocean Systems; Small Business innovation Research; Engineering Education and Centers Division programs (Engineering Research Centers and Industry-University and State-Industry-University Cooperative Research Centers); and the Electrical and Communications Systems Division Programs. Most of these programs have jointly engaged in interdisciplinary research focused on innovative approaches to CIS problems.

DIRECTORATE FOR BIOLOGICAL SCIENCES (BIO). Research supported by the Biological Sciences Directorate (BIO) on genetic, biochemical, physiological, and economic traits of organisms in relation to their physical environment offers a way to understand and improve the role of living organisms in infrastructure deterioration.

DIRECTORATE FOR COMPUTER AND INFORMATION SCIENCE AND ENGINEERING (CISE). The CISE Information. Robotics and Intelligent Systems Division includes the Robotics and Machine Intelligence program, which funds research in automated intelligent machines and sensing systems. This includes robotic systems for excavation, material handling, exploration, construction, and repair; computer vision and other advanced sensing and metrology systems for automated construction; and nondestructive testing and inspection. The Database and Expert Systems program funds information systems research relevant to facilities design, data management, and fault diagnosis.

DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES (EHR). CIS research is intrinsically interdisciplinary, relying heavily on scientific and engineering research, education, practice, and methodology. Programs that support undergraduate engineering and science education (particularly at the introductory level), laboratory development, engineering and scientific research in CIS-related areas, faculty enhancement, and career and graduate program access constitute a significant portion of EHR activity.

DIRECTORATE FOR GEOSCIENCES (GEO). All engineered structures and societal lifelines are subject to environmental stresses and natural hazards. These include high winds, floods, wave action. marine corrosion, freezing and thawing, and earth movements ranging from sudden earthquakes to prolonged soil creep. GEO supports research on characterizing these environmental factors and assessing the resulting natural hazards.

DIRECTORATE FOR MATHEMATICAL AND PHYSICAL SCIENCES (MPS). MPS supports many activities that are related or relevant to CIS. Materials research addresses the preparation, processing, and properties of advanced and novel materials for structural applications, communications, sensors, energy storage, and transportation. Materials chemistry, surface chemistry and physics. electrochemistry, analytical chemistry, and photochemistry contribute both to development and construction of infrastructure and to understanding and preventing its deterioration. Theoretical and computational research in support of CIS areas includes development of modeling and simulation techniques and performance prediction. Many research topics in mathematical sciences contribute in important ways to deterioration science, assessment technologies, and renewal engineering. Research in physics and astronomical sciences, leading to high-speed data acquisition devices and improvements in the state-of-the-art measurement science, has long-term implications for CIS.

DIRECTORATE FOR SOCIAL, BEHAVIORAL AND ECONOMIC SCIENCES (SBE). CIS-pertinent programs supported by this directorate have critical, farreaching social and economic significance in renewing and maintaining the physical infrastructure. Research to improve the physical infrastructure must address the need for viable urban economies, strong urban tax bases, and a trained urban work force.

["Advanced Materials Agenda for the Clinton Administration and the 103rd Congress," by SACMA and USACA; and "Materials Industries' Strategic Needs for the

21st Century," by the Council of Past Presidents of the Federation of Materials Scientists may be found in the committee's files.]

Senator ROCKEFELLER. Thank you. We have had a vote go off.

Senator BURNS. I am going to go vote. I have got—may I make a comment?

Senator ROCKEFELLER. Yes, you may.

Senator BURNS. I get a big kick out of your comment that says why things fall apart. All we have to do is look at the automobile industry. Cars fall apart the day they are paid for; is that right? Did you ever notice that?

Senator ROCKEFELLER. Yes, I do. That is an important issue. [Laughter.]

Senator BURNS. The day you make your last payment, that is the day they start falling apart. And so what I have always said, you know, on some of these bridges, maybe if we never get our counties out of debt, if we keep making payment on a bridge, it will stay forever. That does not happen that way.

Dr. BORDOGNA. Mr. Chairman, one comment I might add that ties a lot of this together is when you were mentioning that you and Senator Burns were looking at some of the changes this system might bring, make some things happen, is to give an example of something that recently happened and affects the Federal Government and why some of this is not working.

One of our largest construction companies, Pan Cor Builders out in California had been funding research through their own side and in cooperation with the National Institute of Science Technology, the University of Michigan, National Science Foundation, and others for a number of years on carbon fiber-reinforced concrete.

And the research on that goes back many years. And for the last 10 years, it is being used in Japan and Europe on buildings. We have not been able to use it here commercially in buildings.

So, Pan Cor Builders had an opportunity with the Army Corps to build a building for them in the southern part of the United States. And they won the job. The proposed to use carbon fiber-reinforced concrete, which had already been tested overseas and used in practice.

It has been tested with some of their own funding in NIST to verify all of the results. They got the Army Corps to agree. They got the Governor and the Senator of the State to agree. Then GSA was the one that had to build the building. And they went and met with GSA.

Senator ROCKEFELLER. And they said, "No."

Dr. BORDOGNA. And GSA said, "No. We are not here to test innovation in practice. That is not our rule."

And so it stopped there. The project went on to be built under normal means. Yet here is the risk in that being absorbed to large extent——

Senator ROCKEFELLER. Is that documented, that example?

Dr. BORDOGNA. Yes.

Senator ROCKEFELLER. Would you send it to me?

Dr. BORDOGNA. I would be happy to.

Senator ROCKEFELLER. May I ask a final question, gentlemen? Because I think, in fact, by the time we go and vote and come back we will be out of time. Also, we have already asked a lot of ques-

tions. And I know I may and I assume Senator Burns may have written questions that we want to submit to you that would cover some of the material that we have discussed this morning. And if you could get that back within 10 days or 2 weeks, I would appreciate it.

If I could ask each of you to express your frustration: If you were God, what has to happen to make advanced materials and progress in fact come together in this country?

Let me start with you.

Dr. BORDOGNA. I have a straightforward answer to that. It goes back to the leadership question again, plus the team. I think we have to work together across the Government agencies, Government with industry. States are very important to this. States are where much wealth gets created through local and economic development and the action happens——

Senator BURNS. That is where the wealth is created.

Dr. BORDOGNA. Yes. We have to synergize it.

Senator BURNS. It ain't created here.

Dr. BORDOGNA. No. Wealth creation happens locally, in regional communities. And technologies gather around in communities. So, we have to synergize all of that. We have to take the talents in each agency and put together a team. Well, we have got that going.

That still is not enough. We have to have a spokesperson at a high level who says, "This must be done." And I think that is a simple thing to do, if you really believe in it. I think the resources are around to do it. The people are around to do it. The knowledge is around to do it. But we have to do it in an integrated way.

Senator ROCKEFELLER. We have got to proceed to Mr. Bernstein, because Conrad and I have about 6 minutes left for our vote.

Mr. BERNSTEIN. I think it has got to come from the top. There has got to be Government policy, as there is overseas. In Europe, in Japan, the government establishes the policy.

They have been using advanced materials and other types of products. And it is a done deal. The United States does not work that way. We need a champion. We need the Government to be partners of that and to absorb some of the risk in trying new innovation practice. And we have to modify a little of the procurement practice to enable us to introduce innovation so that low-cost bid is not the only way to go.

Senator ROCKEFELLER. Should schools of engineering be accredited to teach if they do not offer the advanced materials to work in that?

Dr. BORLESKE. It depends on the school. But, you know, accreditation and making sure that the schools are prepared to move engineers into the future with the latest in technology, I think, should be a requirement.

Mr. BERNSTEIN. I think what you have heard here today is lots of exciting opportunities. Any time people talk about advanced materials, they get really excited about the potential.

We are not bringing these to market. We talked about the risks. I think the most important thing to do is the leadership, with the Government as the customer, leading into the market and making people work together to overcome the barriers which are the standards that go to specification and the manufacturing technologies.

Do not assume that everything that we have talked about, and there are a lot of the good ideas, that you can get them into the marketplace. There are a variety of complexities, manufacturing as well as code standards, and what not. But CERF is the leader in trying to overcome barriers.

Senator ROCKEFELLER. Dr. Davalos.

Dr. DAVALOS. Yes. I think that we should very efficiently tap into the success and experience that the so called small companies that I identified today have been able to harness. And to match this experience with the technology and the capabilities that the larger companies possess to be able to develop the market for advanced composites in the civil infrastructure.

Senator ROCKEFELLER. In thanking all of you in adjourning this hearing, I am told by Patrick Windham, who has put all of this together for the Commerce Committee, that there has not been, as far as he can remember, a hearing on advanced materials in the field of construction in the Senate.

So,a lot of leadership to be brought forward. Thank you all very much.

. [Whereupon, at 12:00 p.m., the hearing was adjourned.]

APPENDIX

QUESTIONS ASKED BY SENATOR ROCKEFELLER AND ANSWERS THERETO BY DR. BORLESKE

Question. How much of the advanced materials technology is available right now to be used on our infrastructure and how much will require additional development before we can apply it?

Answer. While Advanced Materials technology offers significant potential to solve civil infrastructure problems based the benefits observed in the aircraft/aerospace, automotive, naval and other military oriented applications, very little of the technology as it exists today can be DIRECTLY applied to today's problems. The technology package must be tailored to civil infrastructure needs. Much of the effort required is to prove to the civil engineering community that the advantages demonstrated in other market segments translates to their segment and that the design and manufacturing processes exist for the products the industry wants. The technology has been invented, now we have to apply it to a new market area.

*Question.*In FY93, the federal government is expected to spend about $2.0 billion on advanced materials research. Clearly, this technology is not suffering from lack of government support. What recommendations would you make to enable us to get more from our current research efforts in the U.S.? How much of that research is focused on civil infrastructure problems?

Answer. The issue relative to federal funding of advanced materials research (over $2.0 billion/year) is not how much, but the focus of the programs. Most of the Federal funds in the civilian arena today focus on doing the research; very little focus on applying technology to existing problems. In the area of civilian infrastructure, NSF and DOT have funded university-based research and studies (on the order of $50-$70milllon/year). This effort is creating a valuable technology base, but industry is not translating this technology to a commercial offering. Federally supported civilian technology programs should have a commercial product mission Just as the defense R&D programs have a military product mission. Two key ingredients to enhance our current research effort are: (1) define a mission for the research that is connected to a real world problem, and (2) increase the number of technology demonstration programs that show the utility of research and development efforts and facilitate the commercialization of technology.

Question. What are the principal barriers to applying advanced materials research to infrastructure problems?

Answer. The principle barriers are the financial and liability risks and the long commercialization time that an individual company would have to bear if they choose to commercialize a new advanced materials technology in the civil infrastructure area. These risks and lengthy development cycle could be reduced significantly if the customer were willing to share the risk and if several companies and government agencies worked cooperatively to develop this market. Qualifying new materials through the complex maze of codes and regulations is clearly one of the major obstacles. The Federal government as a key user of civil infrastructure improvements has the opportunity to serve as the influential first customer both by stimulating demand and reducing cycle time to meet codes and regulations in this emerging market.

Question. It is my understanding that a wealth of advanced materials technology already exists in the defense and aerospace industry. Those industries have already developed composite materials which are lightweight, corrosion-resistant, strong and durable for use in planes, rockets and weapons systems. What are the barriers to transferring this existing technology to the general construction industry?

Answer. To transfer the technology of advanced materials developed in the aircraft/aerospace industry and other military applications to the construction industry. the construction designer and customer must have a high level of comfort that these materials will meet industry design criteria and perform the required function with advantages over the incumbent materials. Advanced materials like composites

do not have the advantages of history of use in these markets. To build this confidence, the federal government has the unique opportunity to be the influential first customer- to be the first customer to take the risk to try something new(composite bridges, water supply systems, building systems, etc.). The most effective means to develop the required confidence is to sponsor a range of demonstration projects that can be used to develop design data bases and to serve as visible proof that the technology does indeed provide the proposed benefit. The Federal Government in cooperation with the State and local governments should use their purchasing power to spread these existing technologies to new markets.

Question. In a world of advanced materials, what additional training, if any, would our workforce require to be competitive?

Answer. The advantage of advanced materials is the specific solution tailored to solve a specific problem. This requires a high level of skill in design and manufacturing based on math, science and computer technology and a thorough understanding of Quality manufacturing and management principles. The current government efforts to elevate workforce training through high school, vocational school, and college partnerships with industry are much needed in the advanced materials field

Question. As we know, countless technologies have been developed in the U.S. only to see Japan and other nations commercialize them. How does the U.S. avoid a repeat of that in the advanced materials area? Is the U.S. currently on track to commercialize technologies like synthetic concrete, self-healing material, and self-monitoring structures?

Answer. The U.S. is on track in the civil infrastructure market to repeat our success in research and failure in commercialization that we experienced with the VCR and other electronic and automotive technologies versus our global competitors. Most of the advanced construction technologies (smart materials for example) are laboratory research projects rather than commercial development projects. Both Japan and a number of European countries recognize the potential of applying advanced materials technologies to construction and infrastructure problems. They are aggressively supporting cooperative research, development and demonstration programs between industry, academic institutions and various forms of government that focus on commercializing new technologies in the construction and infrastructure markets. Recent changes in Federal Technology Policy that directs federal support towards industry-defined civilian technology targets, such as Clean Car and other surface transportation needs, civil infrastructure opportunities, environmental issues, etc. and focus on demonstration projects are clearly two steps in the right direct in regaining our global competitiveness. We need to continue to drive the cooperation of government, industry, and academe to break open new markets.

Question. Other than throwing more money at the problem, what can the federal government do to insure a better match between advanced materials research and industry requirements? Would you favor a relaxation of antitrust laws to enable firms to work together on the commercialization of technology? (Current lawn already allow cooperative basic research.)

Answer. If the Federal Government looks upon itself as a key customer for the use of advanced materials in civil infrastructure applications, there are many functions the customer serves:

- funding demonstration projects and stimulating demand by incorporating advanced materials into government civil infrastructure projects is the number one priority. This creates market pull and creates industry interest;
- thorough discussions with all parties involved in the offering to make sure the customer needs are well understood (look what happened to U.S. auto manufacturers when they started to listen to their customers); The Department of Transportation should take the lead here with other agencies participating as appropriate. DOT & NIST are currently leading an initiative to define infrastructure material needs with the help of the Civil Engineering Research Foundation.
- requiring that key members of the value chain work together for the best and most economical product (relaxation of antitrust laws would be helpful here); The Department of Commerce model of strategic partnerships would work well here.
- streamlining and enhancing the purchase and requisition process (including standards and codes) to facilitate the adoption of new innovative technology, and
- communicating the value of the new products from Government/Industry/Academe demonstration projects broadly in the industry to accelerate use by private firms.

In summary, advanced materials hold the promise of significantly upgrading our aging and deteriorating civil infrastructure. Industry by itself cannot afford the liability and financial risk to commercialize new products in this market segment. The Federal government in cooperation with State and local governments are key customers for this technology and as such can play a very influential role in reduc-

ing the entry barrier for commercialization of advanced material products. DuPont and other advanced material companies greatly appreciate the interest and the leadership of the Senate Committee on Commerce, Science and Transportation in this area.

QUESTIONS ASKED BY SENATOR BURNS AND ANSWERS THERETO BY DR. BORDOGNA

Question. How much of the advanced materials technology is available right now to be used on our infrastructure and how much will require additional development before we can apply it?

Answer. Much of the advanced materials technology applicable to civil infrastructures requires additional development and testing. The real issue is the availability of functional materials for civil infrastructure in large quantities and at a low cost. Additional research and development must be done to address many fundamental issues about materials properties and practical issues crucial to broad engineering implementations including environmental capability, life-cycle costs, and quality control requirements and procedures. Only then will we have materials that meet serious requirements for use in renewal and enhancement of civil infrastructure.

Question. In FY 1993, the federal government is expected to spend about $2.0 billion on advanced materials research. Clearly, this technology is not suffering from lack of government support. What recommendations would you make to enable us to get more from our current research efforts in the U.S.? How much of that research is focused on civil infrastructure problems?

Answer. The interagency Advanced Materials and Processing Program has allowed the federal government to focus its overall commitment to materials technology and to concentrate on a broad set of goals. Only a small percentage (perhaps 5-10 percent) of the research activity in this program is specifically targeted at materials for the construction industry. However, a much wider range of the research activity (perhaps 25-50 percent) is applicable to civil infrastructure, which broadly defined includes transportation, energy, communications and environmental systems. As NSF's effort in civil infrastructure systems develops, we plan to coordinate the two efforts to ensure they support one another appropriately.

Question. What are the principal barriers to applying advanced materials research to infrastructure problems?

Answer. The principal barriers are: (1) the need for education and training of engineers and other professionals who design, operate, and maintain the infrastructure systems as to the properties and performance standards of such materials; (2) lack of publicly accepted designs codes and materials standards for the application of advanced materials in civil infrastructures, particularly at the state and local levels; (3) socioeconomic, regulatory and political barriers, such as ineffective systems for managing liability for loss and injury resulting from the introduction of new materials, and government procurement practices which discourage the use of new technologies; (4) lack of experience in the use of advanced composites in long-term operation or service in infrastructures; and (5) lack of ability to produce functional materials in large quantities at low cost with the desired properties.

Question. It is my understanding that a wealth of advanced materials technology already exists in the defense and aerospace industry. Those industries have already developed composite materials which are lightweight, corrosion-resistant, strong and durable for use in planes, rockets and weapons systems. What are the barriers to transferring this existing technology to the general construction industry?

Answer. Many of the barriers to transferring existing technologies to the construction industry are technical. They arise from the fact that the requirements for materials in the defense and aerospace industries are quite different from those in civil infrastructure. For example, the objective in a jet fighter is high performance which requires low weight, high strength and high fatigue resistance. Therefore, materials with a high stiffness-to-weight ratio and a high strength-to-weight ratio are required. Composite materials which meet these performance requirements are often very expensive. In contrast, weight is a less critical factor in civil infrastructure, which may have more stringent requirements for control, ease of maintenance, and ability to withstand environmental and load impacts, such as traffic, weather, etc. A key issue for civil infrastructure materials is the ability to produce large quantities at low cost. Therefore, additional research and development must be done to enable the transfer of existing aerospace materials technology to the civil infrastructure sector.

Question. In a world of advanced materials, what additional training, if any, would our workforce require to be competitive?

Answer. Additional training of the workforce is essential for the successful application of advanced materials. Better training in science and mathematics is needed to enable workers to more effectively deal with new information systems, advanced production methods, automated material handling systems, etc. Equally important is further education for engineering and scientific professionals about the theories, applications, and benefits of composite materials before we do any major conversion from present techniques. Indeed, engineers currently in the civil sector are not fully prepared to deal with the design of materials such as reinforced concrete. More frequent contacts among academic, government and industry professionals will strengthen the skills of the workforce and better sensitize researchers to industry concerns.

Question. As we know, countless technologies have been developed in the U.S. only to see Japan and other nations commercialize them. How does the U.S. avoid a repeat of that in the advanced materials area? Is the U.S. currently on track to commercialize technologies like synthetic concrete, self-healing materials, and self-monitoring structures?

Answer. Yes, it is possible that other nations could commercialize advanced materials technologies developed in the U.S. But the U.S. currently has the edge over potential foreign competitors in global commercialization of composite materials in civil infrastructure because we have a deeper technological base resulting from successful, high-tech advanced materials research. However, significant barriers to commercial implementation still exist in the U.S., and other countries, such as Japan and Germany, will be strong future competitors. New research results suggest that the U.S. maintains its lead, although with increasing difficulty, because of its commitment to research excellence in the sciences and engineering.

Question. Other than throwing more money at the problem, what can the federal government do to insure a better match between advanced materials research and industry requirements? Would you favor a relaxation of antitrust laws to enable firms to work together on the commercialization of technology? (Current laws already allow cooperative basic research.)

Answer. The civil infrastructure sector is made up of many companies, public utilities and government agencies at all levels. These entities have already cooperated to apply research advances to industry through professional organizations such as the Welding Research Council and the Structural Stability Research Council, which provide additional linkage between research and practical application. NSF has a successful track record of drawing together industry, academic research and other government agencies to develop integrated, cross-cutting research programs that use limited research resources effectively. We are currently looking at innovative new management concepts such as virtual organizations and enterprise forums that would make an initiative in civil infrastructure even more effective.

As to the issue of the relaxation of antitrust laws, NSF does not have sufficient knowledge or expertise in this area to provide an expert opinion. It is a complicated issue that would benefit from further research.

LETTER FROM HARVEY M. BERNSTEIN, PRESIDENT, CIVIL ENGINEERING RESEARCH FOUNDATION

JUNE 24, 1993.

Senator BURNS,
U.S. Senate,
Washington, DC 20510

DEAR SENATOR BURNS: The Civil Engineering Research Foundation (CERF) appreciates this opportunity to respond to the "additional questions" of special interest to Senator Burns.

Our review of his questions is especially encouraging for they focus on issues in the U.S. infrastructure and construction sector (including introduction of advanced materials and systems) that are the particular concern of CERF.

It is important to note, first, that CERF, in conjunction with numerous federal agencies, academe and the construction sector/civil engineering profession we represent, has already proposed national programs targeting the specific concerns raised in the senator's questions.

Specifically, CERF has already taken three important steps towards identifying and addressing the issues. First, CERF convened a national Civil Engineering Research Needs Forum in 1991 of over 300 nationally recognized civil engineering leaders from industry, the public sector and academe resulting in the identification of five (5) thrust areas and 35 critical research/development needs, one of which is

advanced construction materials. A copy of the Executive Report Setting a National Research Agenda for the Civil Engineering Profession was given to the Senator.

The second and third steps have focused on understanding the global environment in which the U.S. construction sector must compete. CERF's 1991 Task Force Trip to Japan focused on the unique cultural, economic and social conditions that have enabled the Japanese to rapidly move research and development results (including, in many instances, U.S. initiated R&D) from the laboratory into commercial application. Our Task Force Report Transferring Research into Practice: Lessons from Japan's Construction Industry (particularly Chapter 5) answers some of the questions posed by Senator Burns.

The "lessons learned" from Japan has prompted CERF to undertake a complete analysis of civil infrastructure systems R&D in six Western European countries (the United Kingdom, Sweden, Germany, the Netherlands, Italy and France). Again, CERF's focus is on the "systems approach" used by these countries to move innovative construction technology into practice.

Using insights gained from the 1991 Japan Task Force visit, CERF has already united the industry, government and academic communities through the actual establishment of the first of several innovative technology evaluation centers, the Highway Innovative Technology Evaluation Center or HITEC. HITEC is directly focused on resolving the difficulties associated with moving U.S. innovative research/development from the laboratory into commercial practice.

Most of the questions raised by Senator Burns on high performance construction materials are documented and answered in the Executive Report to the President and Congress on High Performance Construction Materials and Systems: An Essential Program for America, and Its Infrastructure. This report responds fully, or in part, to each of the "additional questions" to include recommended actions for the federal government Those responses are as follows:

Question. How much of the advanced materials technology is available right now to he used on our infrastructure and how much will require additional development before we can apply it?

Answer. Virtually all advanced materials technology is available now for application to infrastructure problems on a prototype or demonstration basis. This response has to be tempered, however, by several important considerations including costs, risk minimization, and liability. It is imperative that "partnering" by the public and private sector, as well as incentives for innovation, be used to stimulate use of these technologies. A more detailed response on particular advanced materials is enunciated in the report.

Question. In FY93, the federal government is expected to spend about $2.0 billion on advanced materials research. Clearly, this technology is not suffering from lack of government support. What recommendations would you make to enable us to get more from our current research efforts in the U.S.? How much of that effort is focused on civil infrastructure problems?

Answer. Federal expenditures for advanced materials has been, and is, significant. Spending on advanced construction materials, however, has been minuscule, as indicated graphically on page 12 of the High Performance Construction Materials report. Moreover, it is important to note that while there is, as yet, no explicit federal funding for a national program for high-performance construction materials, CERF has taken the lead in coordinating a national program as elaborated in the report. Funding of a national program (at a relatively modest $2 billion over ten years) is a central and vital recommendation in this Executive Report (see Executive Summary page 30).

Question. What are the principal barriers to applying advanced materials research to infrastructure problems?

Answer. Pages 16-19 of the Executive Report identifies the primary barriers. Barriers lie within the construction sector, in the public sector and in society in general (i.e., risk and litigiousness). Only a concerted and integrated reaction to the collective set of barriers promises to effect the rapid implementation of these materials into wide-spread practice.

Question. It is my understanding that a wealth of advanced materials technology already exists in the defense and aerospace industry. Those industries have already developed composite materials which are lightweight, corrosion-resistant, strong and durable for use in planes, rockets and weapons systems. What are the barriers to transferring existing technology to the general construction industry?

Answer. This question is already answered in a previous question; however, it must be noted that some of the materials developed for specific aerospace applications are at this time cost-prohibitive for use in infrastructure applications and may not be appropriate given the widely divergent desired/required performance characteristics.

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Question. In a world of advanced materials, what additional training, if any, would our workforce require to be competitive?

Answer. Additional training will be the "sine qua non" for introduction of advanced materials into construction/infrastructure applications. This is recognized and embedded in the proposed national program (see page 17). The exact training will vary depending upon the process required for each advanced material. The need for training is not unique to these advanced materials; traditional construction materials, such as concrete and steel, require continual training of the work force as improved concrete and steel, with different properties, are introduced into practice. In this sense, the construction workplace is evolving in the same fashion as other U.S. industries.

Question. As we know, countless technologies have been developed in the U.S. only to see Japan and other nations commercialize them. How does the U.S. avoid a repeat of that in the advanced materials area? Is the U.S. currently on track to commercialize technologies like synthetic concrete, self-healing material, and self-monitoring structures?

Answer. This is, and should be, a central concern for U.S. policymakers as it is pervasive across the spectrum of U.S. industries. No national program, per se, can entirely solve this dilemma. Instead, it requires an active federal policy, in coordination with industry and academe, to identify critical technologies, in every industrial sector, and create the opportunities for these technologies to be commercialized in the United States, by U.S. companies. CERF's proposed national program clearly offers the U.S. construction sector this opportunity but the very fragmented nature of this sector will pose significant challenges.

Question. Other than throwing more money at the problem, what can the federal government do, to insure a better match between advanced materials research and industry requirements? Would you favor a relaxation of antitrust laws to enable firms to work together on the commercialization of technology? (Current laws already allow cooperative basic research.)

Answer. The National Coordinating Council or NCC proposed for this program (with its mix of industry, the public sector and academe) is a necessary first step to ensure that the nation's decisionmakers are both informed of and able to input appropriate policy into the program as it progresses. Second, strong central coordination through the Office of Science and Technology Policy (OSTP) is essential to ensure that the program is fully and properly implemented as it progresses. The NCC annual reports to the President and the Congress will serve as a primary basis for program implementation and necessary modifications.

SUMMARY

The use of advanced materials in the civil infrastructure are embedded in two larger, complex issues faced by the United States; revitalizing the nation's infrastructure and ensuring the global competitiveness of the U.S. construction sector. These are issues that CERF, acting on behalf of the construction sector and the civil engineering profession, is attempting to solve with the invaluable assistance of key federal agencies and academe.

We look forward to working with Senator Bums in promoting advanced technologies for infrastructure needs.

Sincerely,

HARVEY M. BERNSTEIN,
President.

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